JAN 27 1959

ELECTROMECHANICAL components & systems DESIGN

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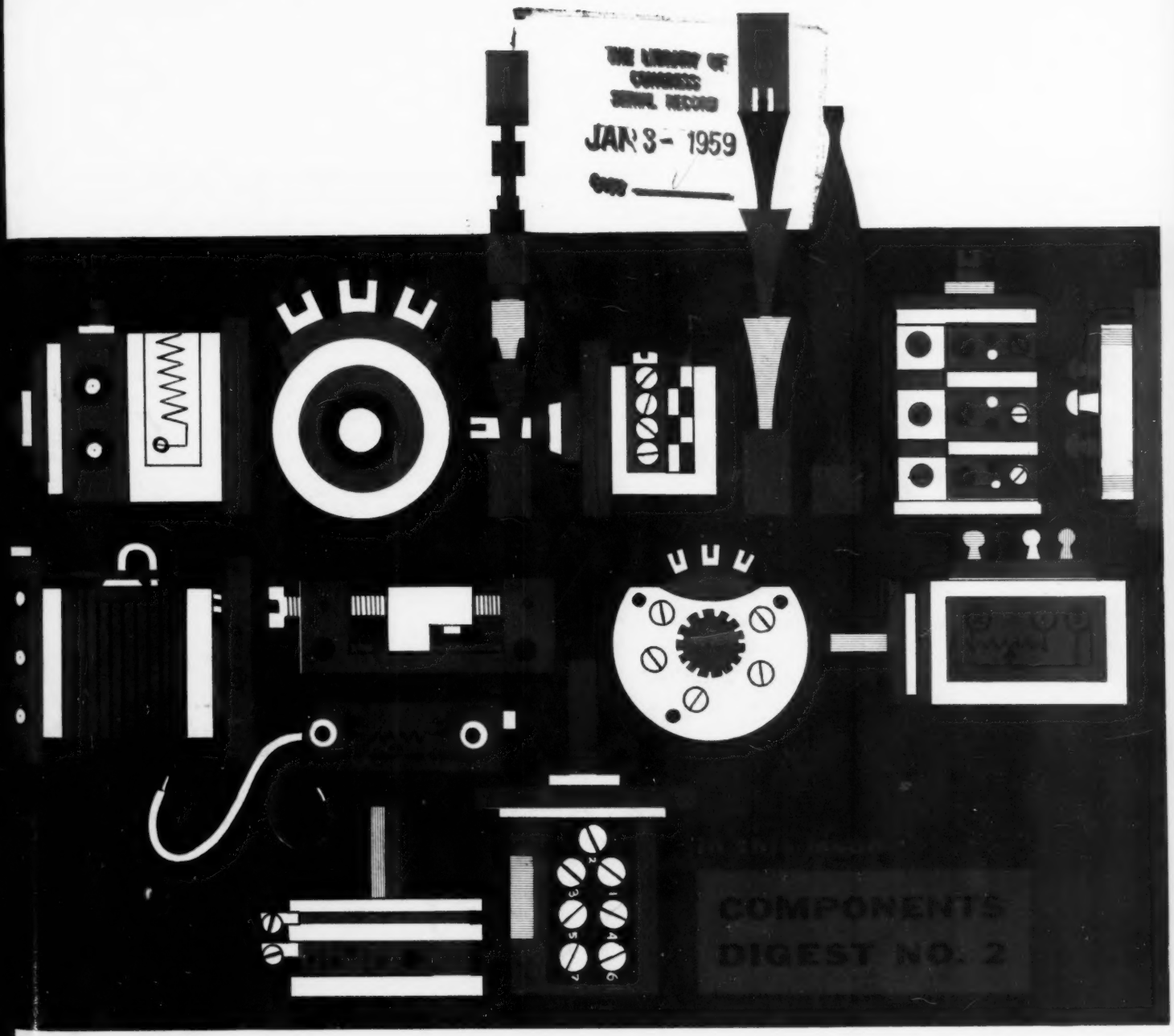

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CIRCLE 1 ON INQUIRY CARD

JAN 27 1959

The Sourcebook of Design Ideas in Applied Electromechanics

ELECTROMECHANICAL components & systems DESIGN

VOL. 2 NO. 10

DECEMBER 1958

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Progressive rather than catastrophic nature of failure in carbon film pots permits analysis of events leading to failure and reveals solution of potentiometer design problem.

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New resistance winding design produces 3.5 megohm resistance in a 2 inch diameter pot using 1 mil wire.

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COMPONENTS DIGEST II

This issue features Components Digest II—a handbook and buyers' guide on precision potentiometers. Consistent with our Components Digest philosophy, we have aimed at a complete and systematic coverage of the topic from the viewpoint of the application engineer who must make an intelligent selection and purchase. Design data, selection factors, pertinent standards, bibliographical references and purchasing information, as well as the Master Chart of typical available components for easy "comparison shopping" add up to an integrated handbook of potentiometer data. Our goal: to save you time in choosing the right component, to steer you to the several manufacturers who make the type of item you want for final discussion and selection.

These Digests are under the overall direction of Components Digest Editor Davis who will be glad to get your comments on how we can make these digests more useful to you.

AND OTHERS TO COME

Undoubtedly, many of you will have suggestions and editorial contributions for our future Components Digest sections, so here's an advance schedule of our 1959 program:

February	Electromagnetic and Potentiometer Transducers
March	Environmental Design and Testing
April	Sensitive Relays
May	Connectors and Fasteners
June	Analog-Digital Converters
July	Recorders and Indicators
August	Switches
September	Fractional Horsepower Motors
October	Vehicle Reference Systems
November	Sub System Packages
December	High Temperature Components

In February we shall cover under Electromagnetic Transducers: synchros, resolvers, differential transformers, microsyns, magnosyns, synchrotels and absolute pressure transducers.

Under Potentiometer Transducers we shall cover: very low torque potentiometers (under 0.01 oz. in.), linear motion potentiometers, accelerometers with potentiometer outputs and various voltage and current pickups.

We'll be happy to incorporate your suggestions on these topics if they reach us in sufficient time.

Robert B. Brotherston
Editor

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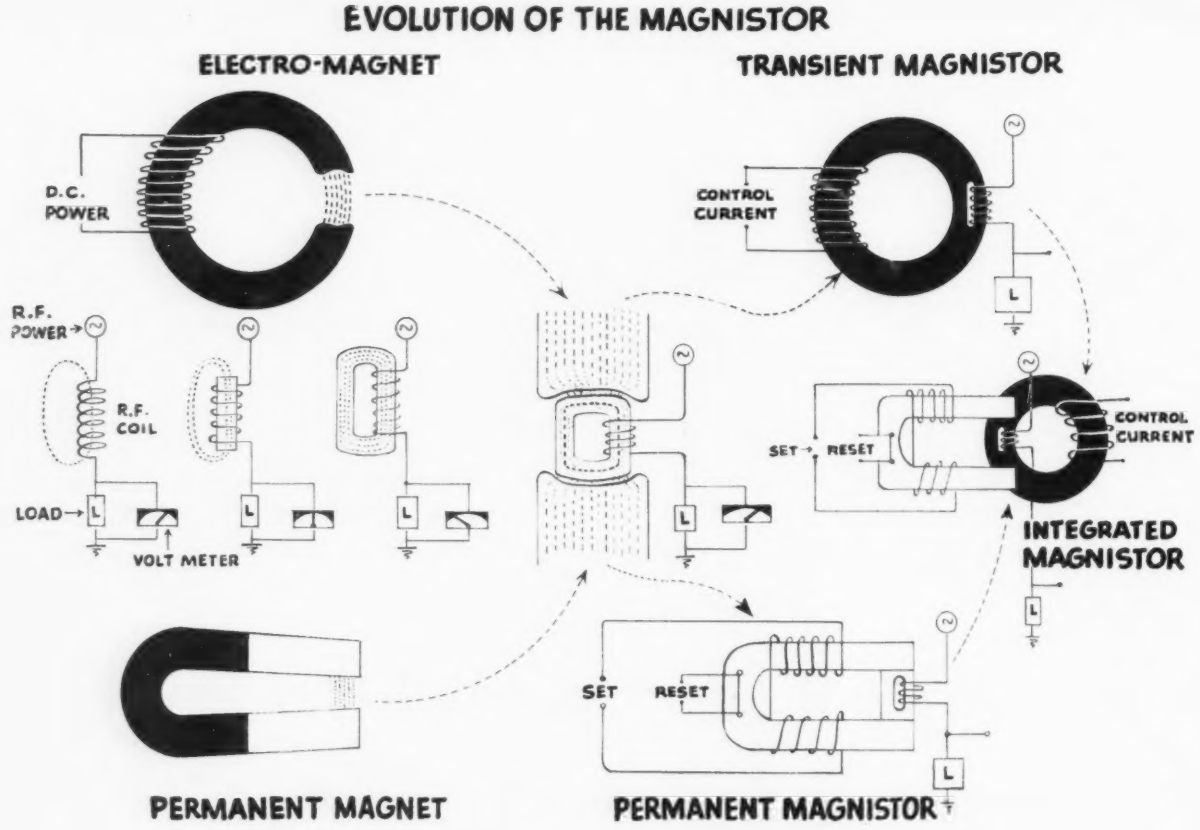


Evolution of the Magnistor can best be approached by examining the three coil diagrams at the left. The air core RF coil, in conjunction with a suitable load, causes the meter to register large voltage; in other words, the RF coil presents a low drop to the flow of RF current. When a slug core is inserted, increasing the number of flux lines, the indicator shows a midway position. Since the inductance of the coil has been increased thereby removing some of the RF voltage from the load, completely enclosing the core with a toroid creates a maximum of flux for a given number of ampere turns and a given ferrite structure. The toroid maximizes the absorption of power supply voltage and the meter shows a minimum voltage. The maximum and minimum states are made use of in data processing applications concerned with *off* and *on*, *zero* and *one*, *yes* or *no*. The center diagram shows the elementary structure placed between the poles of either a permanent magnet or an electromagnet. These magnets externally create the maximum and minimum states by overcoming the coerciveness of the circulating flux resulting from the coil and reduce the inductance of the coil to that of an air core state. This mode of operation forms the basis of either a transient magnistor or a permanent magnistor. These are combined in the integrated magnistor joining the advantages of a magnetic circuit with an electrical circuit.

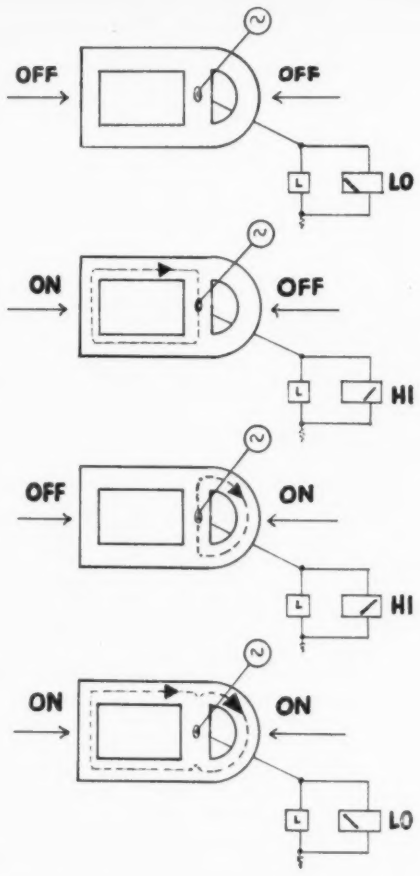
INTEGRATED MAGNISTOR

Improved Component for Control Systems

Several years ago Richard L. Snyder, a Potter Instrument Company consultant, developed what he called a transient magnistor and a permanent magnistor. Transient magnistors are high-speed saturable reactors in which an alternating electric current in the form of a sine wave carrier or pulses is passed through what is called a signal winding and modulated by variations of current passing through what is called a control coil. The permanent magnistor has the property of memory associated with the ability to handle appreciable power. Its signal coil is similar to that of a transient magnistor but control is effected by means of two coils called the "set" and "reset" coils. A current pulse through the "set" coil causes the impedance of the signal coil to be low; the condition persists after the pulse has passed whether or not power is present in the signal circuit. High impedance is restored to the signal coil if— and only if—a current pulse passes through the "reset" coil.

Mr. Snyder developed these units as a control component that could displace the vacuum tube and the transistor in the synthesis of complicated controls. Initially, Mr. Snyder developed the magnistor for amplifiers, gates and logical networks. His choice of magnetic principles was based on three inherent advantages of this approach. First, other magnetic devices such as transformers and magnetic amplifiers have extremely long life expectancies. Second, the magnetic link between the electrical circuits provides isolation between controlling and controlled circuits which is not to be had in any other known single device. Third, an additional degree of freedom in design was available in the choice of the shape and magnetic characteristics of the core which provides a very powerful means of making simple elements of remarkably versatile characteristics. Note that independence between the controlled and the controlling circuits in the magnistor design permits the cascading of many elements without the use of special coupling networks.

This quality in simple amplifiers reduces the number of auxiliary circuit

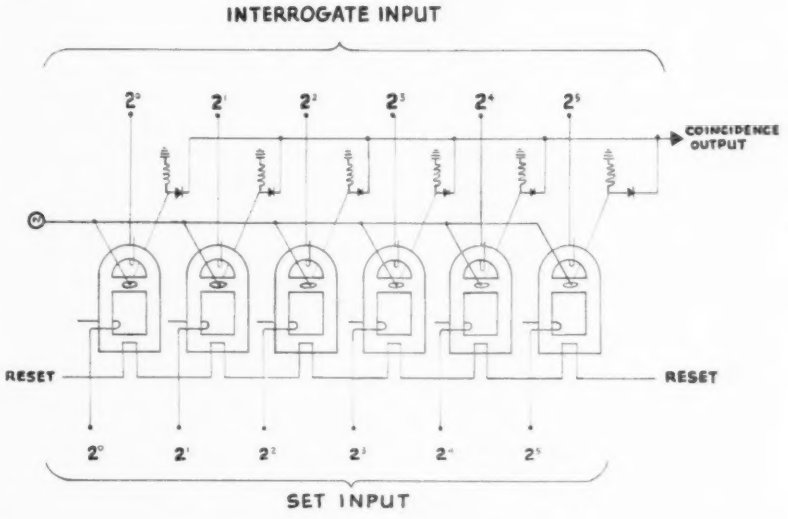


The Four Logical States of the Integrated Magnistor

The four logical states of the integrated magnistor indicate its application to data logic. The square section of the structure represents the permanent magnet or high-residual material; the rounded portion represents the transient material; and the vertical bar in the center represents the signal winding section or the output portion. The top figure represents an *off* condition since the two inputs are not energized. No flux flowing to the signal portion presents maximum induction to the signal winding leading to an indication of minimum output voltage because of the absorption of the high inductance of the signal winding. The *on* state applied to the permanent section results in saturation of the signal winding section, giving an indication of high across the loads since the impedance of the signal winding is now at its minimum value. The third figure down has transposed the *on* to the transient side and the *off* is restored to the permanent side. Output indication is high since the signal winding is again at a low impedance level; in this case the signal winding receives flux from the rounded portion. The fourth and last case is the one which is unique and perhaps not ordinarily anticipated. With the simultaneous application of the *on* state to both the permanent and transient sections, proper polarization of one winding with respect to another orients the direction of flux flow so as to cancel out the flux that would be expected to flow in the signal section. In effect, it is not a cancellation as such; it is merely one where the transient structure has sufficient ampere turns supplied to produce an electromagnetic force which makes the virtual reluctance of the part appear to be a good deal less than the part represented by the reluctance of the signal winding section. This causes the flux stored in the permanent section to take a path around the transient section, removing the flux which previously (case two) flowed through the signal winding section. Interesting conclusions drawn from the examination of all four cases shows that a balance of *off* and *off*, and *on* and *on* gives the same indication—a unique and desirable element for applications in digital processing.

APPLICATION OF THE INTEGRATED MAGNISTOR TO DATA LOGIC

Digital processing equipment, in which comparisons are continually made between information stored in devices such as registers against information transiently occurring or being fed from a tape handler, present a specific application for the integrated magnistor. The illustration shows six elements or six bits in a binary coded alpha-numeric character comparison by coincidence detection. Signal input to the permanent sections are set in from tape, from a computer or from any source generating six bit information or transferring six bit information which is ultimately printed out. Stored six bit information is compared against identical equivalent information being internally generated. When a match occurs—a parity condition between the *ons* and *offs* for each bit—there is a drop in potential at the common line output, sending a signal to an output device. Note that the combination of each of these circuits (including the resistor and diode) forms a common circuit such that only when all of the output signal winding outputs are low will the common bus potential be low. When any one is high, the bus voltage is high.



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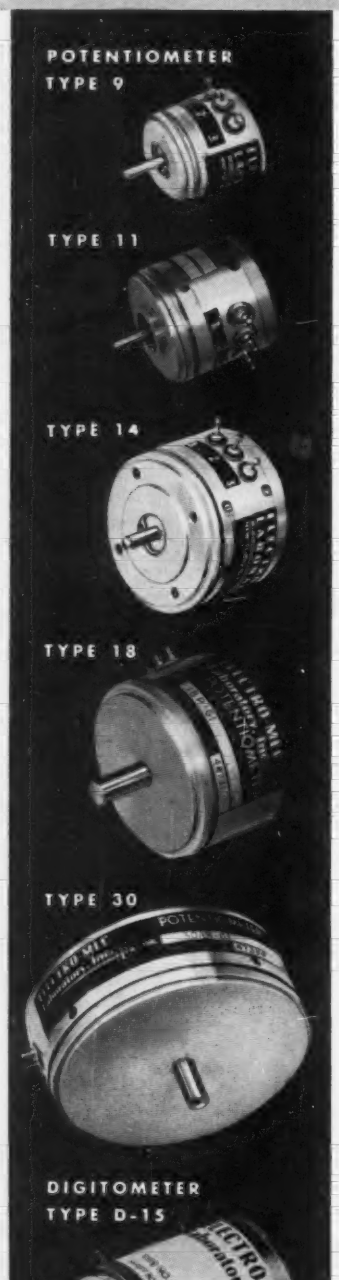

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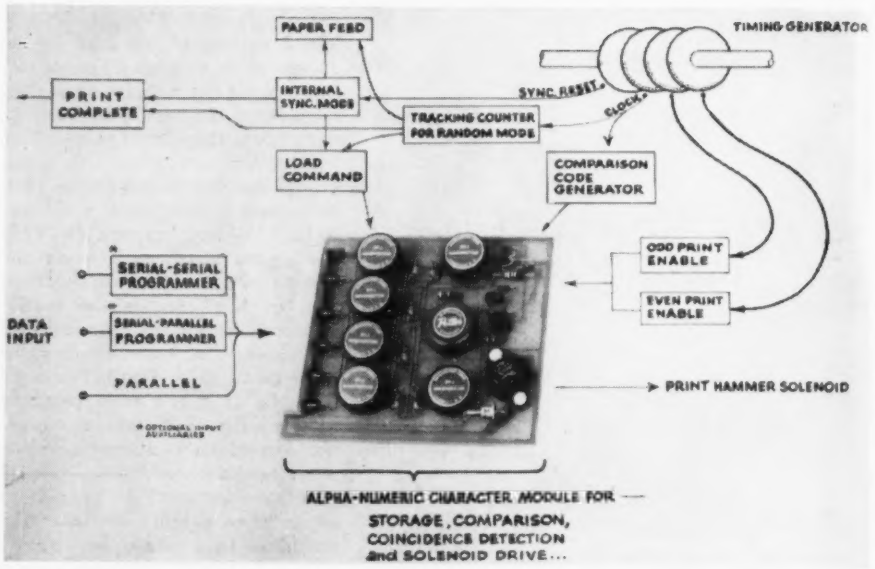
COMPONENTS DESIGN



This photo illustrates the integrated magnistor applied to the Potter high-speed page printer and data lister. The central portion is a photograph of a plug-in module used with Potter high-speed printers. Six integrated magnistors form the six bit elements for alpha-numeric information; the centrally capsulated unit is a ten megacycle oscillator. The timing generator enables the particular or specific interrogation of the information stored in the magnistor and ties in the printer operation with the interrogation of the stored data. Two modes of operation are possible for a printer, depending upon the nature of the external data and the method of its synchronization. One is random mode operation, in which the printer is slave to external data; in the other the printer is master (internal sync. mode) and everything external to it a slave. Normally a 120 column printer requires close to 8,000 cores with external auxilliary circuitry. Above module containing integrated magnistors significantly reduces the complexity and amount of circuitry. Six transistors shown next to the input connector represent the communication to external sources which forms the inputs of the unit. Lower right-hand portion contains a power transistor that represents the ultimate output of the unit. In this way, the integrated module performs all of the functions associated with a print-out column—an innovation in high-speed electronic printing.

components such as condensers and resistors by a factor of two or more. In more complicated logical devices such as switches, adders and registers, auxiliary elements can be eliminated.

More recently, Mr. Nathan A. Moerman, Potter Instrument Company's Director of Engineering, combined the features of the transient magnistor and the permanent magnistor into a new integrated control component. This combination permits what Mr. Moerman considers to be a new circuit technique, in that he combines magnetic circuits with electrical circuits. Previous designs employing transient and permanent magnistors used a bridge circuit; the integrated magnistor uses magnetic circuits in which the magnetic fluxes are controlled by externally applied currents. Combining the transient and permanent magnistor permits them to share a common signal winding between the two control elements—a unique feature.

Mr. Moerman feels that the magnistor will unquestionably have wide application in the data processing field for manipulations such as: sorting and collating, data search, comparison, parity checking, as well as for a myriad of high-speed control units used in production operations, machine tools and small business accounting systems.

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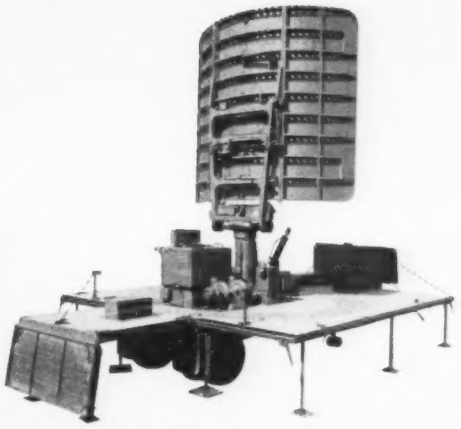

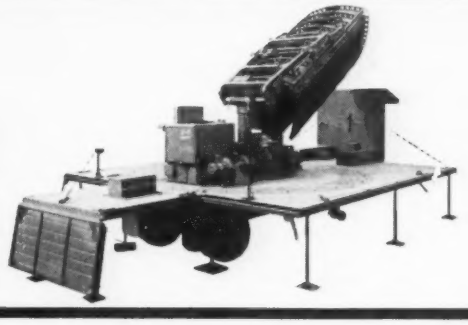

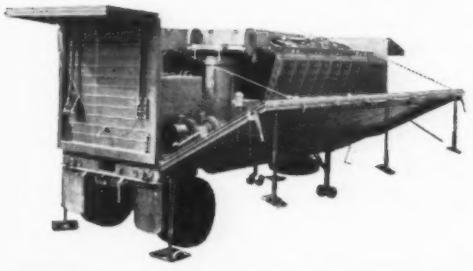

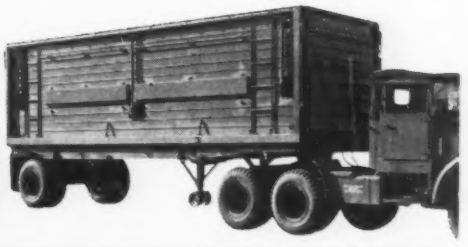

How to conceive a radically improved radar scanning technique. How to integrate this technique into a superior data handling system. How to make the complete scanning and data handling system mobile.

These were the problems faced by engineers at the Hughes Ground Systems Division in Fullerton, California. Utilizing a completely new engineering concept, these engineers developed a radar scanning system which positions beams in space by electronic rather than mechanical means...thereby providing three-dimensional radar protection.

They developed high-speed data processors which monitor the action of hundreds of aircraft and store the shifting tactical situations for high-speed assignment of defense weapons. They produced compact electronic display systems which present the tactical information in symbolic and language form.

And then they made this complete radar and data handling system mobile. The radar scanning antennas (shown above) can be converted for travel on the road in minutes. The complete data processing and radar scanning systems, with all of their wide capabilities, have been engineered to occupy only a few standard size army van trucks.

The research, development and production of this advanced system is typical of the creative engineering now underway at Hughes in Fullerton. If creative engineering is your forte, you will find abundant aesthetic and monetary reward at Hughes. To investigate write to Mr. L. L. Wike at the address below.

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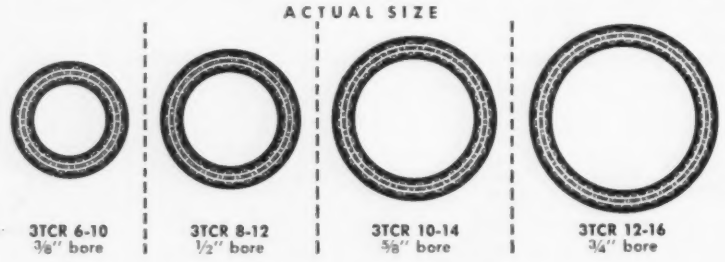

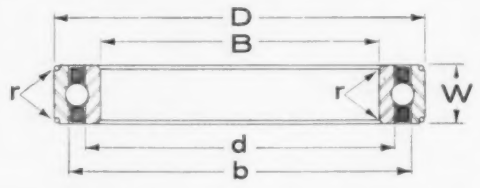

*B bore ± .0002	*D o.d. + .0000 − .0004	W width + .0000 − .0050	†r radius	b outer land ± .001	d inner land ± .001	Balls no.	Balls size	‡L lbs.	§S lbs.
.3750	.6250	.15625	.010	.542	.457	16	1/16	77	110
.5000	.7500	.15625	.010	.672	.587	21	1/16	89	144
.6250	.8750	.15625	.010	.797	.712	24	1/16	94	165
.7500	1.0000	.15625	.010	.922	.8375	30	1/16	101	206

Dimensions are in inches. *Tolerances shown are for Precision Grade. Write for Ultra Precision Grade tolerances. †r is maximum fillet radius on shaft or housing that bearing will clear. ‡Radial load capacity at 500 rpm and 2500 hours average life. §Static non-Brinell load capacity.

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LONG-LIFE FILMPOT

Carbon-Film Resistance to Catastrophic Failure Discloses Current Surges in Circuit

Computer Instruments Corporation of Hempstead, L. I., N. Y., tells a design story that illustrates the value of giving a component manufacturer full application information when ordering a special component.

American Bosch Arma Corp. needed a voltage-dividing linear potentiometer to pick off azimuth of the target-searching radar antenna used in their MD-9 tail-turret fire-control system for the B-52 bomber. Fastened to the antenna and rotating with it at 625 rpm, the pot was to supply to a scope a voltage proportional to antenna angular position. Target position in azimuth could thus be determined by reading the radar antenna position at time of target contact in terms of potentiometer voltage output.

Nature of the scope presentation required that the pot produce a double sawtooth of opposite polarity as shown in Fig 1. Linearity was to be ±0.2 percent of excitation voltage in each 166 degree section, and all angles were to be within 1 degree. Minimum life time of the potentiometer while excited with voltage and operating into the scope was to be 500 hours at 625 rpm, equivalent to some 18,000,000 shaft revolutions; desired lifetime was 2,000 hours or approximately 75,000,000 revolutions.

Arma first tried wire-wound potentiometers. As shown in Fig 2, these were dual gang units, each cup having a winding length of 166 degrees and dual shorted wipers 180 degrees apart. Wire-wound pots consistently failed to perform for the required 500 hours; some failed as early as 50 hours. The nature of failure was an opening at the end of the winding resulting in a sudden loss of trace. Arma diagnosed the trouble as mechanical wear of the winding ends due to wiper bounce and wiper abrasion.

In hopes that substitution of a carbon film resistance element would greatly improve life, Arma presented the problem to C.I.C. C.I.C. first duplicated the pot of Fig 2, using carbon film resistance elements in place of wire-wound ones with suitable changes in wiper materials and pressures, etc.

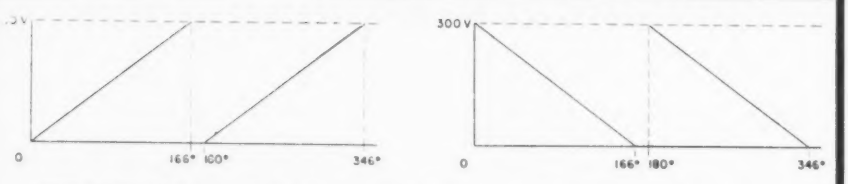


FIG-1 Double-sawtooth forms of pot output required for scope presentation of antenna azimuth.

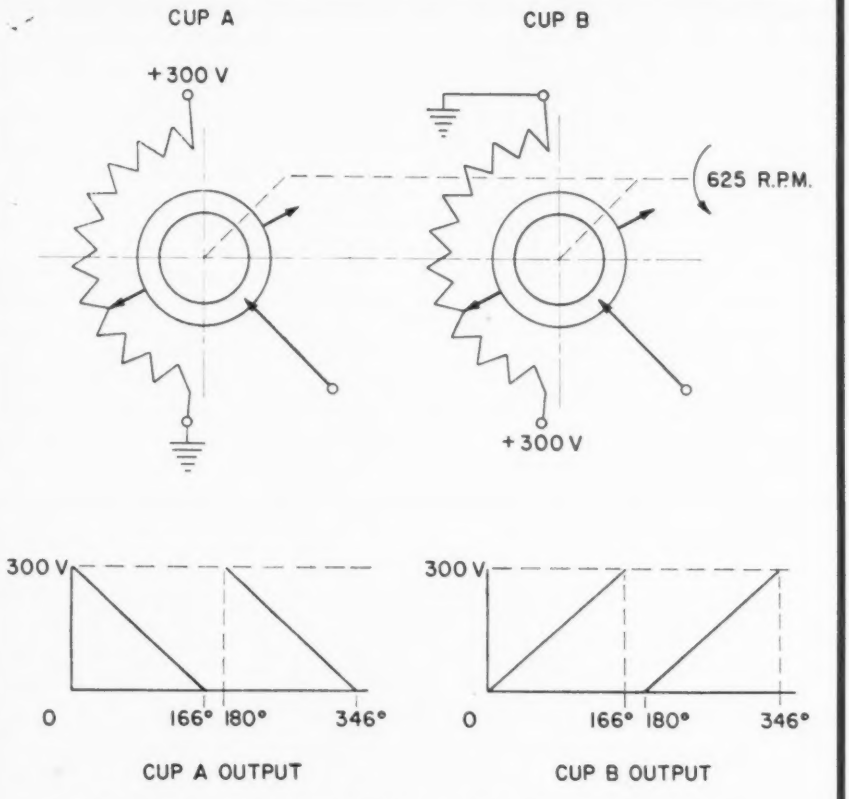


FIG-2 Schematic of first design: a dual-gang, wire-wound pot.

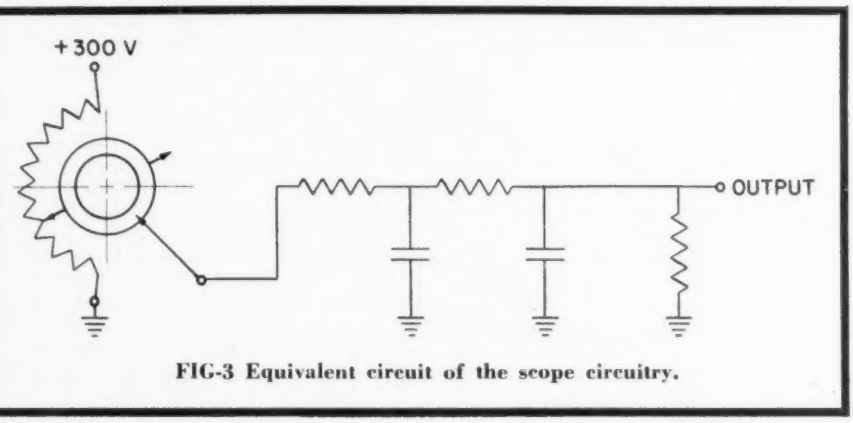


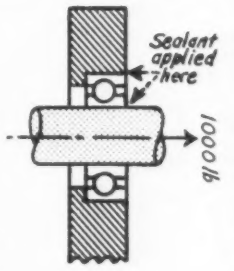
FIG-3 Equivalent circuit of the scope circuitry.

Edwin F. Oblinger, Chief Engineer, Parker Sweeper Company, says:

"WE THREW OUT PRESS FITS FOR BEARINGS..."

"We used interference fits to prevent bearing races from turning in the gear box of our 4HP Turbosweeper. Maintaining close tolerances was a constant headache. If the fit was loose, the race would slip and fret the surfaces; if the fit was tight, the race would deform and bearing life would be shortened. Then we discovered LOCTITE Liquid Sealant would do away with the need for press fits. We opened up the tolerances for both shaft and housing and used a slip fit, filling the clearance with LOCTITE. The bearings are retained with a force equal to the customary interference fit, but we've reduced rejected parts from 8% to less than 1% and reworked parts fell from 20% to 0! Field reports are excellent."

LIQUID SEALANT . . . replaced interference fits and opened up tolerances almost 0.002 in. on shaft and housing for this ball bearing assembly. Load of over 1000 lbs. is needed to break bond.



LOCTITE is a penetrating liquid that hardens only after being confined between closely fitted metal parts. In the absence of air, the sealant hardens into a strong, heat and oil-resistant bond. The hardening action may be accelerated by heating.

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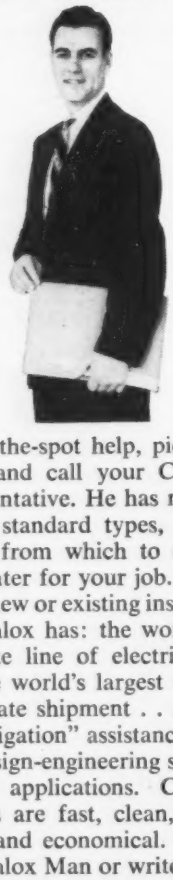

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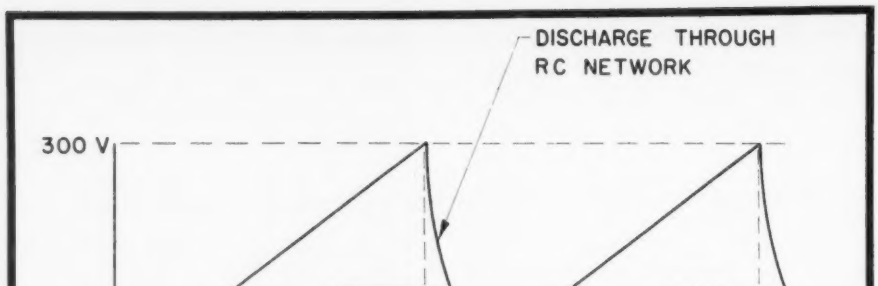

FIG-4 Time plot of voltage output at the pot wiper

This unit failed after approximately 200 hours of running at 625 rpm. Because of unique characteristics of carbon film pots, however, this failure pinpointed the trouble. Past failures in wire-wound pots were sudden, unannounced and catastrophic, the kind that give no warning, and were so complete in effect that this portion of the fire control system was disabled. Carbon film pots yielded a scope trace which at first was clean but then began to show roughness. After approximately 150 hours of running, trace irregularity became increasingly pronounced until final loss of trace.

The progressive nature of failure evidenced in the carbon film permitted reconstruction of events leading to failure. C.I.C. engineers determined that mechanical abrasion was only a secondary cause of failure. Primary cause was current surge in the wiper circuit at the ends of the resistance element, a transient effect induced by the scope circuitry.

C.I.C. thus needed full details on the scope circuitry, which Arma readily supplied. Analysis of this circuitry clarified the pot design problem. An equivalent circuit of the scope circuitry is shown in Fig 3.

As a result of the particular time constants of the RC network and the speed of wiper rotation, the time-plot voltage output at the wiper appeared as in fig 4. Voltage generated during the sawtooth generation discharged through the RC network. Before complete discharge could take place, the

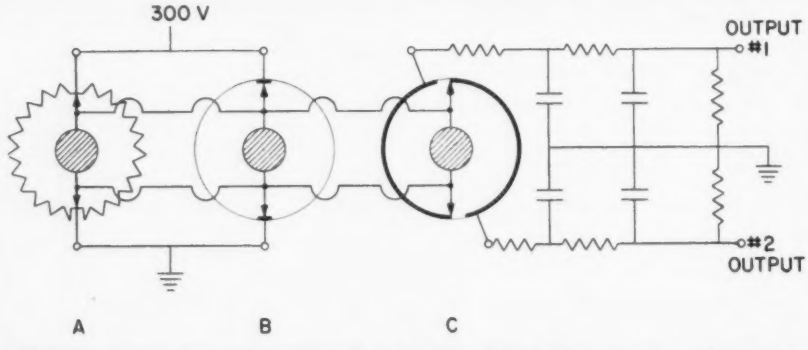

FIG-5 Schematic of Computer Instruments Corp's 3-gang potentiometer-commutator for antenna azimuth pickoff. As wiper 1 on cup A leaves shorted section and begins to wipe along resistance element in direction of increasing voltage, wiper 1 on cup B rides on insulator portion of commutator making no contact, and output is read on output #1 terminal by virtue of wiper 1 on cup C making contact with associated commutator section. Positive-slope sawtooth generation due to wiper 1 movement on cup A is read out through output #1; contact of wiper 1 on cup C is broken, hence readout is interrupted just as peak voltage is obtained on wiper 1 on cup A, and remains broken for 7 degrees of rotation. During this interval, discharge to ground is made through parallel paths of contact on 14 degree sections on cups A and B of wiper set 1. Since the contact resistance is less on cup B commutator bar than on cup A carbon-film resistance element, the surge of current bypasses the element and is carried mainly by the commutator segment. This method of discharge of transients acts on both positive and negative slope sawtooth functions. Positive slope generation appears only on output terminal #1, whether generated by wiper set 1 or 2. Conversely, negative slope generation appears only on output #2.

alternate wiper contacted the ground terminal. The residual voltage suddenly discharged through the wiper and resistance element, producing a current surge of approximately 22 ma. This transient was repeated twice each revolution and cumulative local heating caused rapid deterioration in the resistance element.

In the case of the wire-wound potentiometer, local welding of wiper to windings was taking place; in the carbon film potentiometer, local heating caused the substrate to carbonize, fracturing the resistance film. The repeated transient coupled with mechanical abrasion caused failure. This analysis indicated that a basic change in design philosophy was required. Design objectives were established in three parts:

1. To generate a triangular wave shape through use of a voltage-dividing, continuous-ring, carbon-film resistance element. Wiper was to pass across winding ends, thus minimizing mechanical wear.

2. To switch the segments of the triangular wave shape to produce required positive-and negative-slope sawtooth voltage outputs. A commutator switching cup and two pairs of wipers separated 180 degrees were to produce this action.

3. To reduce the transient effects during the switching of wave shapes by means of current bypass. A small-section commutator cup paralleled with the resistance element was to act as a bypass for transients.

The resultant design by the Computer Instruments Corporation is the three-gang potentiometer–commutator shown schematically and described in Fig. 5.

The design, in production 18 months, has proven itself in field use. Tests of production units on a regular sampling basis have shown life times in excess of 2,000 hours.

Circle No. 62 on Inquiry Card

High-Temperature Circuit Breaker

Designed to function in aircraft at altitudes up to 75,000 feet, a latch-type circuit breaker will interrupt 225 amperes at 480 volts, 400 cycles, three phase. Maximum current interrupting ability is 4000 amperes and circuit breaker will operate within an ambient temperature range of −65F to +600F. Adaptable to d-c applications, the 18.5 lb unit will operate satisfactorily at 250-volts dc and carry 500 amperes for 15 minutes. To reduce failure possibilities, there are no delicate adjustments on the breaker, no bearings, pivot pins, encased plungers, or brazed joints. Westinghouse Electric Corp., Pittsburgh, Pa.

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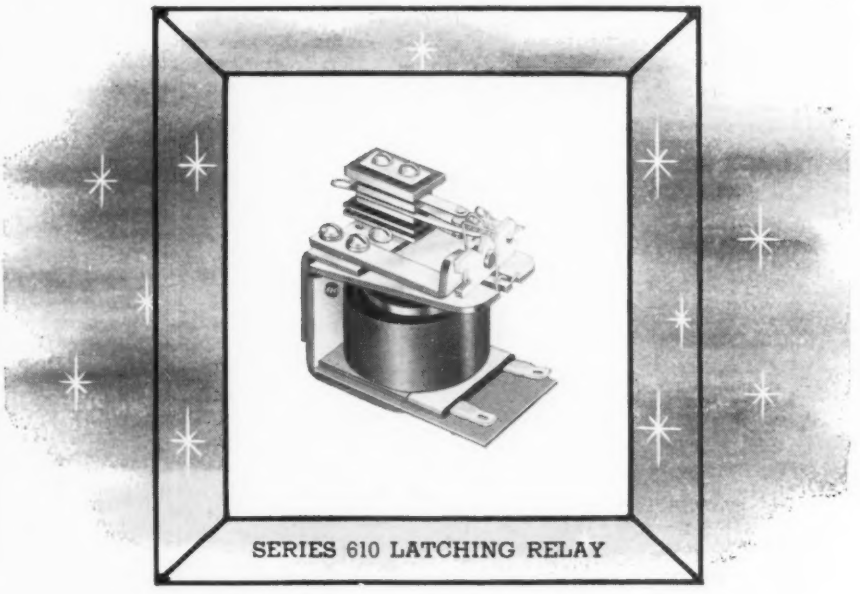

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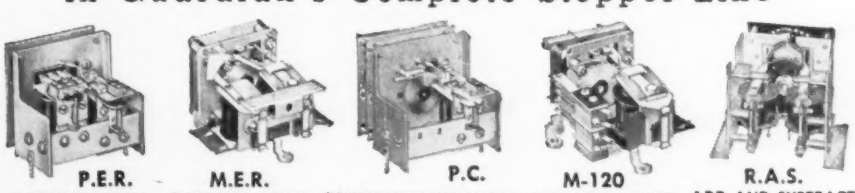

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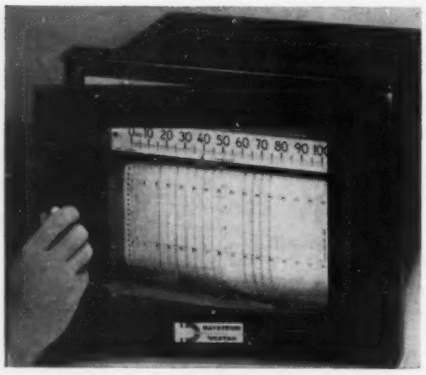


Multipoint Potentiometric Recorder

A new multipoint potentiometric recorder is adaptable from two to twenty-four points by use of simple plug-in adapter units. Should an operator be measuring six points, and additional work load requires that twelve points be monitored, he need only change a plug-in unit and replace a dial indicator and print wheel which are mechanically geared with the selector switch. No new selection switch is needed, no soldering is required, and no refitting of the components is necessary. The entire changeover operation can be completed in three minutes. Range changing requires only the insertion of the proper range clip.

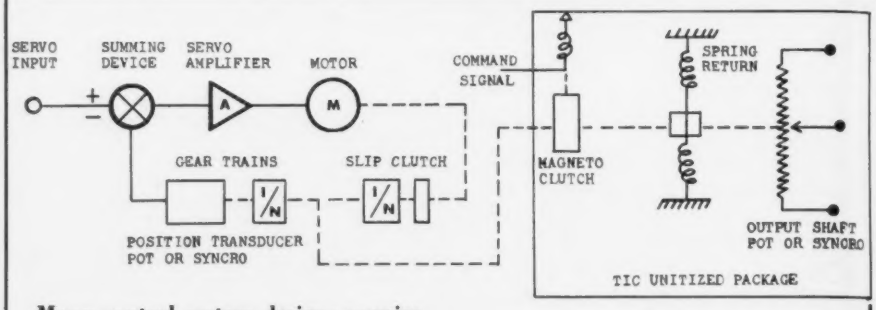
Change in the type of thermocouple or transducer being used is easily accommodated by replacing a newly designed terminal block that has the cold junction compensation integrally wired into it. Inserting the matching range clip and scale plate, which are included in the thermocouple change kit, completes this simplified procedure. The instrument is also easily changed into a pen-dragging type for single-point recording.

The Model 6702 mounts in a standard 19-inch relay rack, and is available for panel or wall mounting. It can be used to measure any inputs from thermocouples or transducers, whether they be voltages, frequencies, temperatures, pressures, pH, etc. All change-overs can be simply effected in the field by screwdriver adjustment through the hinged front door which makes all the parts readily accessible.

The Daystrom Division reports that added features include alarm switches, internal illumination, chart tear-off, high resistance to shock, vibration and corrosion, low spare parts inventory due to interchangeability of all parts, and an accuracy of 1/4 percent.

Circle No. 180 on Inquiry Card

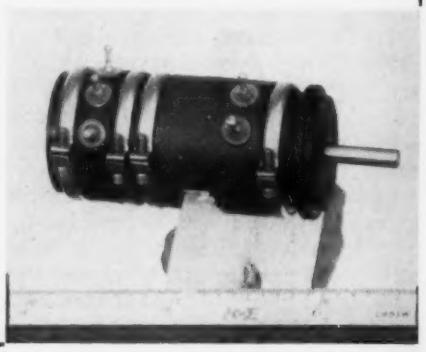
Servo Output Transducer with Independent Angle Reference



Many control system designs require an output transducer that engages a servomechanism gear train at some specified servo position in response to an external command signal and returns to a specified position when the command signal is removed.

Technology Instrument's West Coast engineering group now provides a solution to this problem in one compact assembly: a module consisting of an electromagnetic clutch, spring return mechanism and shaft position transducer. The clutch transmits high torque without slippage and has negligible angular engagement error. TIC's unique spring mechanism accurately returns the output transducer to the desired position and yet requires low driving torque. The shaft position transducer can be a linear or nonlinear potentiometer, synchro, linear transformer or digitizer.

Circle No. 63 on Inquiry Card



Small Megohm Pot

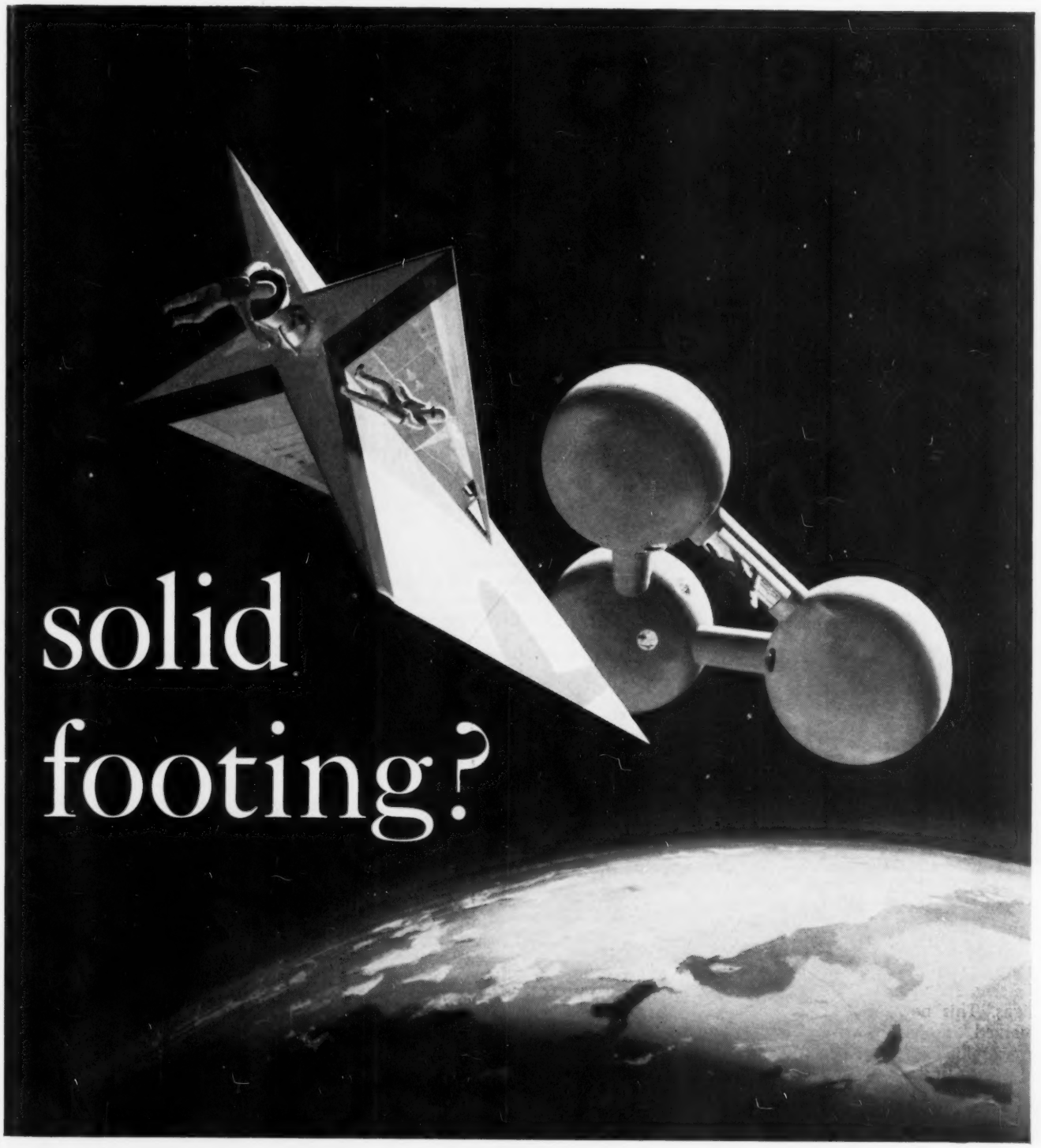
Designers sometimes need very high resistance pots to minimize loading in circuits where pots are cascaded, or in electronic devices for timing or measuring where high resistance is required to match tube characteristics. Users of such pots have until recently been faced with an undesirable compromise between excessive pot size or very fine, unreliable resistance wire.

This compromise can be avoided in a new type of pot developed by Accuracy, Inc., Waltham, Mass. By a novel winding and packaging technique, using one mil wire Accuracy can make a 2 megohm pot in a 1.75 inch diameter or even a 6 megohm pot in a 3 inch diameter. Here's how they do it.

The wire is wound and bonded on a card of conventional size, but the diameter of the winding loops is much greater than the width of the card. Winding the larger loops is accomplished by a technique that is simple to perform, but not to develop.

- The card to be wound is taped temporarily to the surface of a large plastic tube split lengthwise, fitted around and taped onto a wooded cylinder with a plastic spacer. Sides of the card are parallel with the longitudinal axis of the plastic tube.
- Plastic tube with card mounted is wire wound in a lath as a conventional card would be. Size of tube determines resistance per unit length of winding for a given size wire and spacing.
- After being wound, the wire is epoxy bonded to the card. Remainder of the winding is covered with strips of plastic tape, placed parallel with the wires.
- Surface of winding bonded to card is buffed.
- Split plastic tube with winding is removed from wooden cylinder and plastic spacer. Tube is collapsed and winding removed.
- Winding is flattened so that the portion supported by the card forms one edge. Excess of card at ends is removed.
- Card edge of winding is formed into circle and fitted into pot case. Unbonded portion of winding is separated along the edges of the supporting plastic film and folded in like petals of a flower as shown in the illustration.

Circle no. 67 on inquiry card



To a man floating weightless around Space Station C, these are perhaps meaningless words—but *solid footing* is highly important to most of us who live and work on the surface of the earth.

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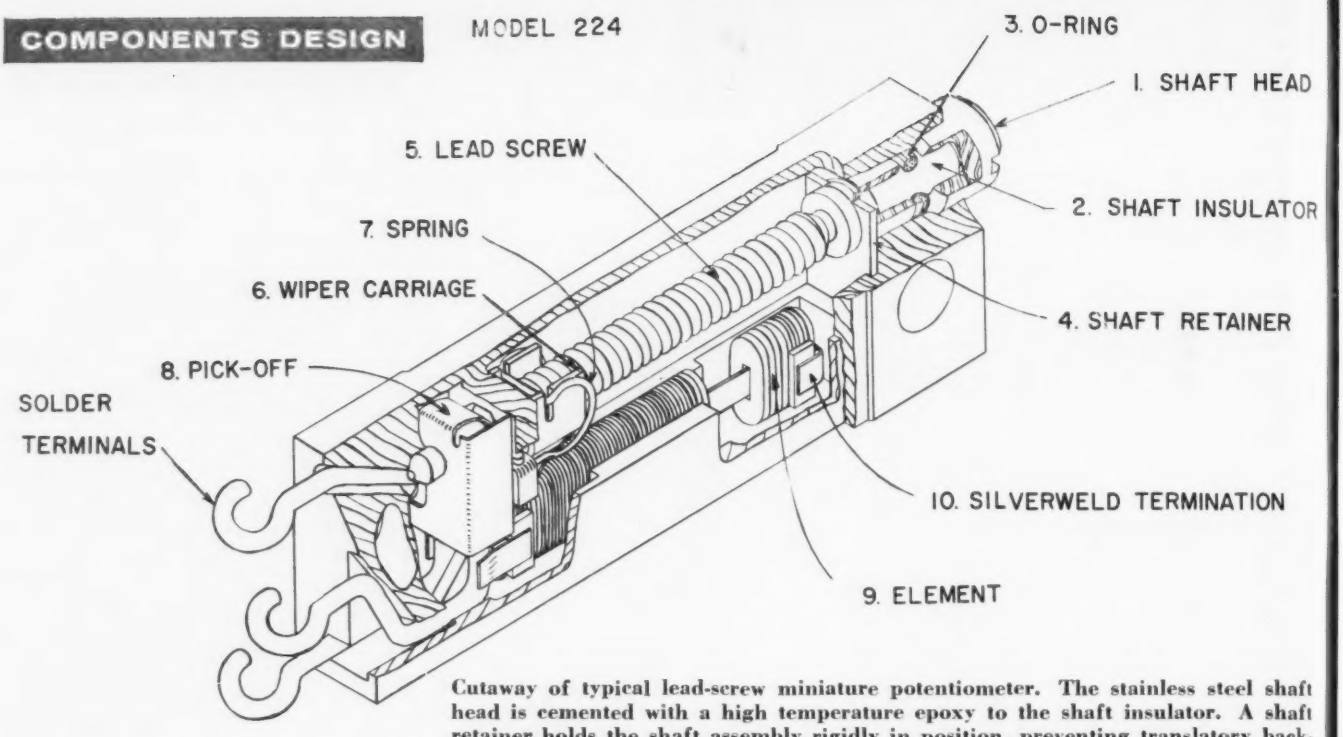

Cutaway of typical lead-screw miniature potentiometer. The stainless steel shaft head is cemented with a high temperature epoxy to the shaft insulator. A shaft retainer holds the shaft assembly rigidly in position, preventing translatory backlash (end play). Lead screw provides 22 turns of electrical travel giving ample angular resolution. A precious metal wiper is welded to the wiper carriage. An electrical pick-off contacts the shaft and provides a noise-free connection to the exterior terminal. Connections to the exterior terminals whether they are insulated stranded leads, solder terminals, or printed circuit pins, are made by the Silverweld process which, in addition to its other advantages, enables the termination to withstand substantial power overloads.

LEAD-SCREW POTENTIOMETER

Tiny Hi-Temp Trimpot Reliable for Extreme Military Requirements

In 1952, engineers of Bourns Laboratories Inc., Riverside, California, originated the lead-screw potentiometer. Since that time they have been improving it. Recently they designed a new adjustable subminiature lead-screw pot as a result of material evaluation conducted as part of the company's monthly Reliability Assurance Testing Program for all military designs. This new Model #224, trademarked Trimpot, meets the most stringent military reliability requirements, and is so small that 16 will fit into one square inch of panel space.

Principal design features of the new unit:

- A special alloy is fused directly to the resistance element providing a true interpenetration of metals with the hard nickel-chrome resistance wire. Because many turns of resistance wire are contacted, this termination is practically indestructable under conditions of mechanical or thermal shock.
- The wiper carriage spring acts as a safety clutch which momentarily skips over a thread should you attempt to force the unit beyond normal travel limits. This prevents damage to the component and eliminates the necessity of frequent replacement.
- The resistive element is a low temperature coefficient nickel-chrome alloy wound under controlled tension on a precision ceramic form or card. Ceramic was chosen for the card because it has low moisture absorption and its thermal expansion characteristic is similar to that of the resistance wire.
- The wiper carriage and shaft are made of all metal parts so their thermal expansion characteristics may be closely controlled.
- An O-ring effectively seals the pot against adverse atmospheric conditions, and provides additional insulation between the shaft and the internal lead screw.
- A sealed plastic case molded from a special high temperature plastic, which resists moisture and doesn't develop corrosive by-products, provides complete humidity protection.

One of the three terminal configurations of the miniature pot. In addition to the solder terminals, the pot is available with insulated stranded leads and printed circuit pins. Complete dimensions are only 0.190" x 0.312" x 1.25", and the unit has standard one inch mounting centers. Units are available in nine resistances ranging from 100 ohms to 50,000 ohms in this wirewound version with a tolerance of ±5%. Later this year a carbon pot with resistances as high as 1,000,000 ohms will be introduced.

BACKGROUND

Bourns engineers claim that originally the lead screw potentiometer was designed to correct two major shortcomings in rotary adjustment potentiometers. First, when used in applications requiring critical adjustments, a rotary potentiometer is difficult to "set" because of its inherently poor angular resolution. Angular resolution is a measure of the angle through which a potentiometer shaft must be rotated be-

fore a change in output voltage takes place. This angle may be 1° or smaller in a typical rotary potentiometer designed for adjustment applications. A small resolution angle, advantageous for servo systems applications, makes accurate circuit adjustment with a screwdriver difficult. A comparable lead-screw pot provides a minimum of 28° of angular resolution and no hunting is necessary to make even the finest of adjustments. Lead-screw actuation allows excellent repeatibility of adjustments and eliminates the chance of a change in setting during service. The built-in friction of the lead screw and wiper block permits stable settings without locknuts.

A second limitation of rotary potentiometers was eliminated by the rectangular configuration of the Trimpot. They may be stacked side by side without the waste space previously resulting from the cylindrical configuration of rotary pots.

SPECIFICATIONS

Initial testing on the Model #224 indicates a conservative power rating of 1 watt at 70° derated to 0 at 175°C, the unit's maximum operating temperature. At 125°C, the unit is rated at 0.5 watt. Other initial specifications supported by test data: operating temperature range, −65°C to 175°C; insulation resistance, 1000 megohms minimum; dielectric strength, 1000 volts a-c, 1 minute; maximum temperature coefficient of complete potentiometer, 0.00007/°C.

Circle No. 66 on Inquiry Card

Tantalum Capacitor

New miniature solid electrolyte tantalum capacitor has exceptionally stable capacity, dissipation factor and leakage current over a temperature range from minus 80°C to plus 85°C. Exceptionally well suited for use in miniaturized electronic equipment such as portable transistorized communication equipment, computers, and equipment that must withstand extremely severe environmental conditions, the capacitor consists of a small sintered tantalum anode on which is formed an oxide film.

The electrolyte is a solid semiconductor material. Anode and electrolyte are both enclosed in a metal hermetically sealed case and are unaffected by humidity and corrosive atmosphere. Three case sizes cover ratings of 2 microfarads at 35 working volts to 240 microfarads at 4 working volts. ITT Components Division, International Telephone and Telegraph Corporation, Clifton, New Jersey.

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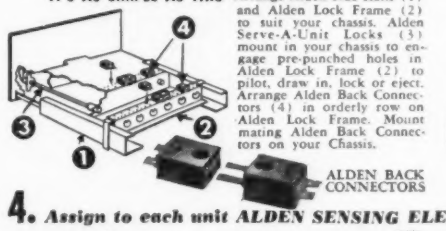

Arrange Alden Side Rails (1) and Alden Lock Frame (2) to suit your chassis. Alden Serve-A-Unit Locks (3) mount in your chassis to engage pre-punched holes in Alden Lock Frame (2) to pilot, draw in, lock or eject. Arrange Alden Back Connectors (4) in orderly row on Alden Lock Frame. Mount mating Alden Back Connectors on your Chassis.

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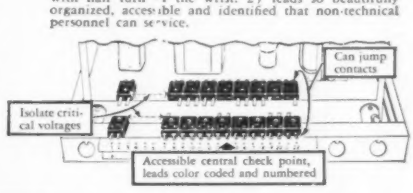

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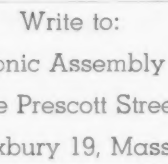

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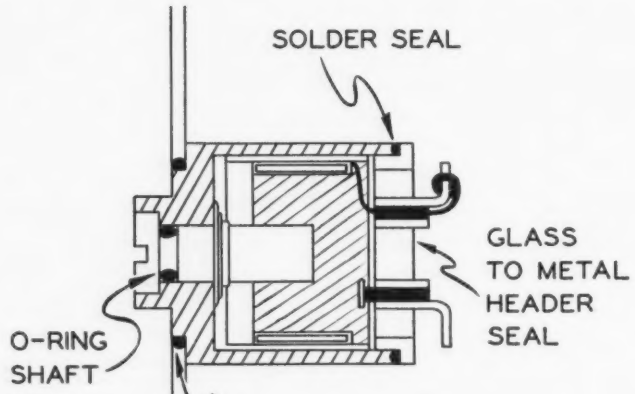


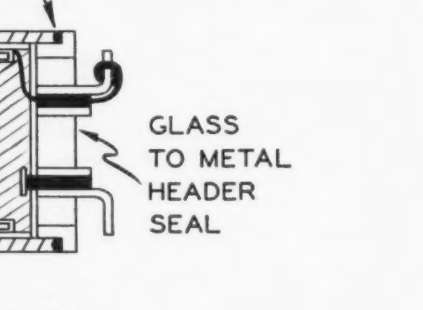
AIRCRAFT PANEL POT

Potentiometers Hermetically Seal Aircraft Instrument Packages

Aircraft instrument manufacturers have been looking for a simple technique to hermetically seal their instrument packages. Necessity of occasionally adjusting or controlling the internal circuitry of the instrument complicates sealing the instrument panel. The conventional technique is to use a pot with a bellows adapter that can be sealed into the panel and used as an adjustment linkage. But the additional bellows increase the size, complexity and cost of the design.

A new ½ inch pot, called the APH ½, designed by Waters Manufacturing, Inc., Wayland, Mass., greatly simplifies hermetically sealing the instrument case and provides precise instrument control and adjustment. Waters' method of sealing is illustrated in the accompanying cross-sectional diagram. The header that holds the terminal lugs at the back of the unit is fabricated at 1200F to make a glass to metal seal. Induction heating used in soldering the header to the pot case localizes heating preventing damage to internal parts of the pot. These techniques completely seal the back of the pot. Pre-tinning the pot so that it can be easily soldered into the panel makes it possible to hermetically seal an instrument package in which the pot is assembled.

In addition to maintaining the hermetic seal behind the panel, the potentiometer itself is sealed against moisture, dirt and salt spray by means of an "O" ring shaft seal, as specified in MIL-E-5272A.



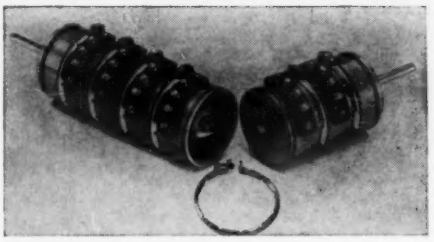
Waters Hermetical Seal Pot is available with mechanical rotation stops, special winding angles, resistance values to 100K ohms and tight linearity tolerances. Rated at one and one-half watts at 125C, the unit is derated to zero watts at 150C.

Circle No. 65 on Inquiry Card

Cathode Ray Oscilloscope

General-purpose oscilloscope requires minimum space and fits easily into crowded installations. Designed for rack mounting in standard commercial racks or cabinets, it features a front panel unobstructed by leads. All operating controls are grouped for efficient operations. Input jacks spaced on ¾ inch centers may be used with standard plug-type connectors and a parallel set of input connectors is placed at the rear of the instrument so that the equipment can be placed permanently in the rack assembly. Push-pull amplifiers are used throughout and the horizontal and vertical amplifiers are electrically identical, making the instrument ideal for work in which phase measurements are to be made at various frequencies. The frequency response extends from DC to 100 KC. Waters Manufacturing, Inc. Wayland, Mass.

Circle No. 187 on Inquiry Card



Change-Quick Potentiometers

Developed to simplify the replacement of potentiometer functions, Change-Quick Potentiometers (patents applied for) are ideal for bread-boarding and development circuitry applications. Individual function cups can be substituted quickly by removing an external clamp, fitting the new cup into position, indexing and phasing it and replacing the clamp. With less than 0.1 degree shaft rotation alignment error, an entire seven-gang assembly can be indexed in minutes by inexperienced help. Ace Electronics Associates, Inc., Somerville, Mass.

Circle No. 136 on Inquiry Card

Wafer Bearings

Series of "skinny" bearings called Microwafers or "wafer" bearings have been especially developed to meet the specific requirements set forth by manufacturers of synchros, servos, small motors, potentiometer and gear trains. In proportion to their outside diameters, wafer bearings have widths narrower than standard bearings. With the technique of through-boring, more iron and copper can be added to rotors and stators without increasing the over-all length of the unit. Thus, greater capacity and better performance can be built into existing designs. These wafer bearings are available in a wide variety of shaft and housing diameters. All have the following characteristics: starting torque—standard at 1400 mg mm under 75gm thrust, 90 percent guaranteed at 1100 mg mm if specified (lower levels by selection); material —440C stainless steel; tolerance—ABEC 7 or better; radial play and lubrication—as specified by customer. New Hampshire Ball Bearings, Inc. Peterborough, N. H.

Circle No. 193 on Inquiry Card

WORTH FILING

Semi-Conductor Directory

Directory covers about 1000 transistors and diodes produced by 13 major manufacturers. Each transistor, diode and rectifier is listed by pot number, name of manufacturer and OEM price in quantities up to a thousand pieces. Directory is constantly revised and issued several times each year.

Source: Allied Radio Corp., Chicago, Ill.

For Your Copy: Circle No. 219 on Inquiry Card

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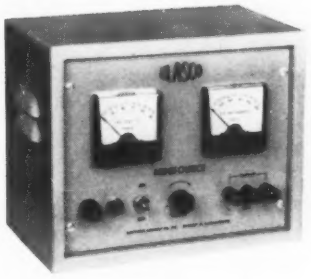

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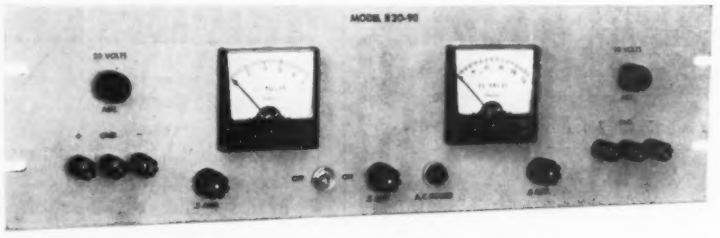

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INPUT: 105—125 V AC

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OUTPUT IMPEDANCE: less than 0.25 ohms, DC—100 kc

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CIRCLE 11 ON INQUIRY CARD

ELECTRICAL ENGINEER'S GUIDE TO INSULATED wire

subject: APPLIANCE WIRE

types: ALL INSULATIONS
including polyvinyl chloride; asbestos; silicone rubber; Teflon; Kel-F; polyethylene; Nylon; etc.

conductors: copper; nickel; nickel clad copper; nickel plated iron; aluminized iron.

source: CONTINENTAL WIRE CORPORATION

For complete information on the many types of Continental insulated wires and cables, write or call CONTINENTAL, Wallingford. Where heat . . . moisture . . . cold . . . oil . . . grease . . . corrosive vapors . . . demand a reliably insulated wire or cable, be sure to specify CONTINENTAL. A wide range of types and sizes in stock, or to special order. Give amperage, voltage, diameter limitations, and operating temperatures and conditions when inquiring.

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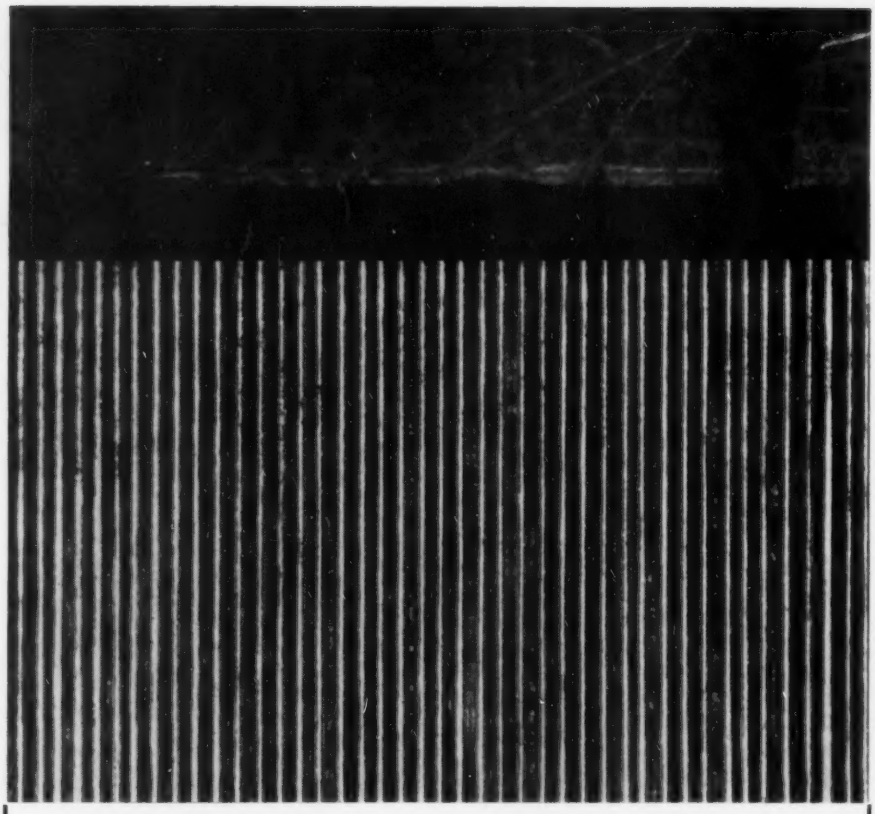


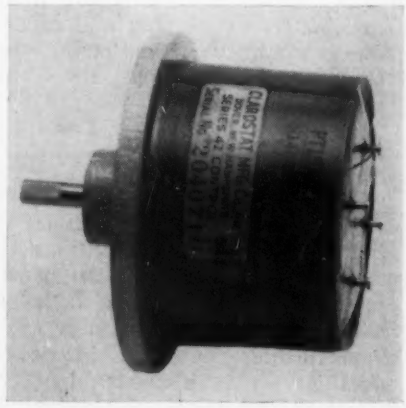
Pot Winding and Spacing Control

Microphoto (60 times magnification) shows extreme parallelism of wires and spacing distance on Ace Electronic Associates, Inc. potentiometers. The distance between two tap markings is 1/16 inch. Ace designed and built their own winding machines to achieve this type of spacing and wire control to deliver 0.1 percent linearity at production costs. Just how these winding machines wind to such accuracy won't be revealed by Ace's president, Aaron M. Solomon or any of his company's engineers. Mr. Solomon reports that the Ace-designed equipment allows optimum control of the wire while the resistance element is wound. Not only is close winding achieved, but the space between each turn is precise to an extent, Mr. Solomon states, unmatched in the industry. Special built-in electronic tensioning devices permit the winding of the wire from 0.0005, with complete repeat reliability. Better control of windings and spacings means a smoother output curve. Ace also uses long-wearing, low-mass, low-brush-pressure contacts for better shock and vibration performance, low noise and long rated life.

Circle No. 64 on Inquiry Card

Sine/Cosine Potentiometer

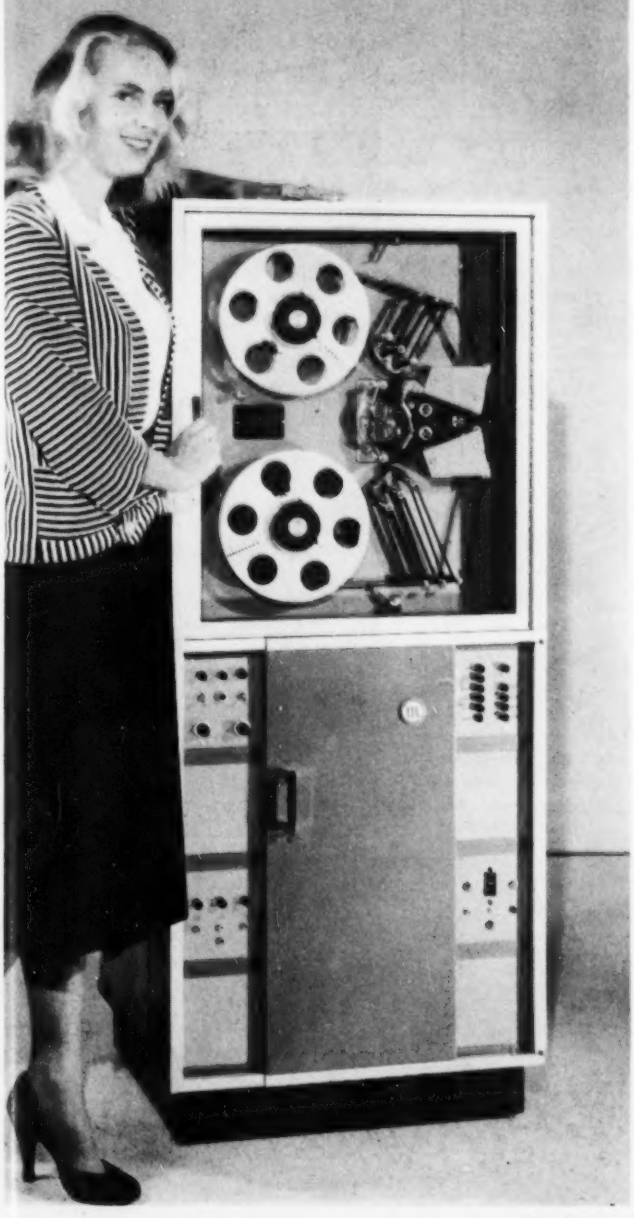
A new sine/cosine potentiometer for use in radar, computer and servo-mechanism assemblies has a standard conformity of plus/minus 1 percent peak-to-peak or a special conformity of plus/minus ½ percent peak-to-peak. Precise windings plus low-wear wiper design result in a guaranteed life of 500,000 cycles and total resistance of 16,000 ohms, plus/minus 3 percent. The unit has a flange mount and employs oil-impregnated bronze bearings for a recommended maximum speed of 30 RPM. Shaft torque is 1.0 oz-in. In addition the new potentiometer will meet humidity, temperature, altitude, corrosion, shock, and vibration tests of



MIL-E-16400A, and humidity requirements of MIL-5272 Precedure I. Clarostat Manufacturing Co., Dover, N. H.

Circle No. 185 on Inquiry Card

new speed in digital data processing



Encompassing the latest in packaging and reliability, Consolidated's new MicroSADIC commutates and converts up to 10,000 analog inputs per second. Outputs are recorded on digital magnetic tape in pre-selected formats compatible with most computers and peripheral equipment. Digitizing may be in either bipolar binary, bipolar binary-coded decimal, or unipolar binary-coded decimal form. Completely transistorized, the system is packaged in modular "slices" for unusual flexibility. Write for complete story in Bulletin CEC 3004-X5.

systems division **Consolidated Electrodynamics**

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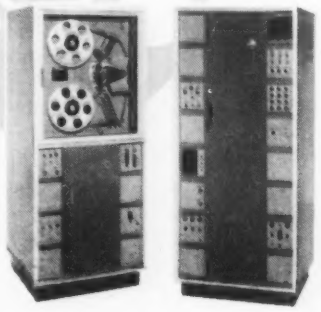


The basic MicroSADIC consists of a commutator, digitizer, system programmer, time programmer, and digital tape unit. All-transistor circuitry on printed boards results in low power consumption and trouble-free operation.

CIRCLE 10 ON INQUIRY CARD

HYPERVELOCITY PHENOMENA

Mirror and Drum Cameras Record Position vs Time

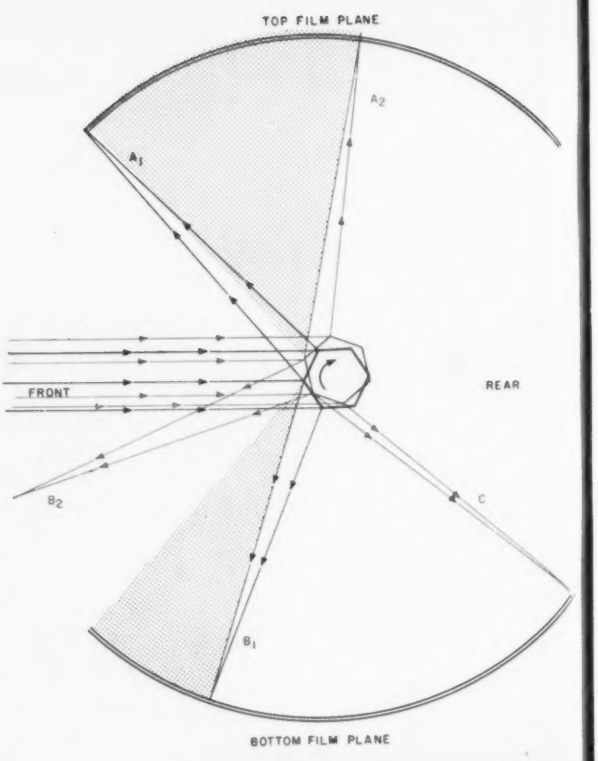
Two laboratory standard, air powered instruments—a rotating mirror and a rotating drum camera—provide accurate and reliable photographic records of hypervelocity phenomena. Originally developed for studying shock tube phenomena in their own research laboratories, Avco Manufacturing Corporation of Wilmington, Massachusetts is now making these instruments available to industry.

The rotating mirror camera records position-versus-time relationships, sweeping the image from a hypersonic object source onto fast emulsion film strips. The rotating drum camera, in addition to making position-time film records, may be used with a densitometer to produce data of hypervelocity phenomena. With a Schlieren system it produces microsecond-order photographic frames for graphical analysis.

Both cameras operate on compressed air, driven through shaped nozzles as turbines integral with either the rotating mirror or drum units. Advantages of only one moving part and one preoperational adjustment—focus which is set and locked—make the cameras inherently simple and reliable. For data reduction, both cameras provide continuous optical records which are readily measurable. Constant focal distances and known rotation speeds of the mirror and drum eliminate the major variable factors for accurate calculation of velocities.

The cameras, say Avco engineers, are valuable in studies of radiation, explosive compound development, solid fuel ignition, propulsion, ballistics combustion, chemical recombination, plasma tunnels, magnetohydrodynamics, spark gap discharges, high speed electromechanical units such as relays and other transient events which emit or reflect light.

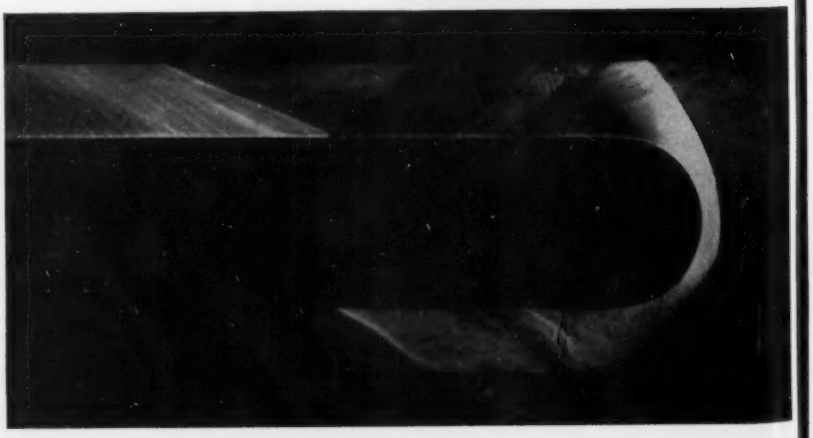
Circle No. 61 on Inquiry Card

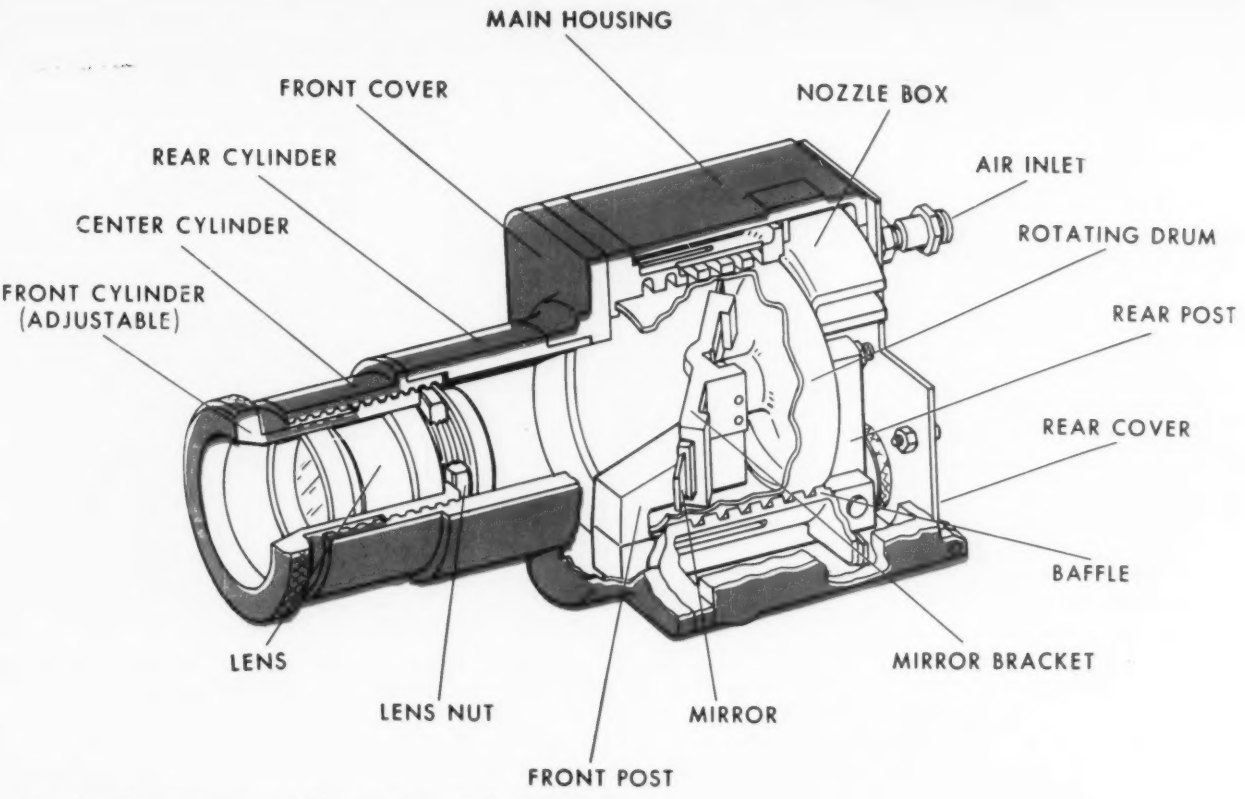


Continuous writing is accomplished by a hexagonal mirror rotating at 3,000 rps for a writing speed of 4 mm/us and a total writing time of 50 us. As rays A expose the film with top film plane from A_1 to A_2 as a result of mirror rotation, rays B expose the film in the bottom film plane from B_1 to front end of film. When rays A are in position A_2, rays C start to expose film so that the event is photographed on top and bottom films with an overlap between the two making synchronization of event and camera automatic.

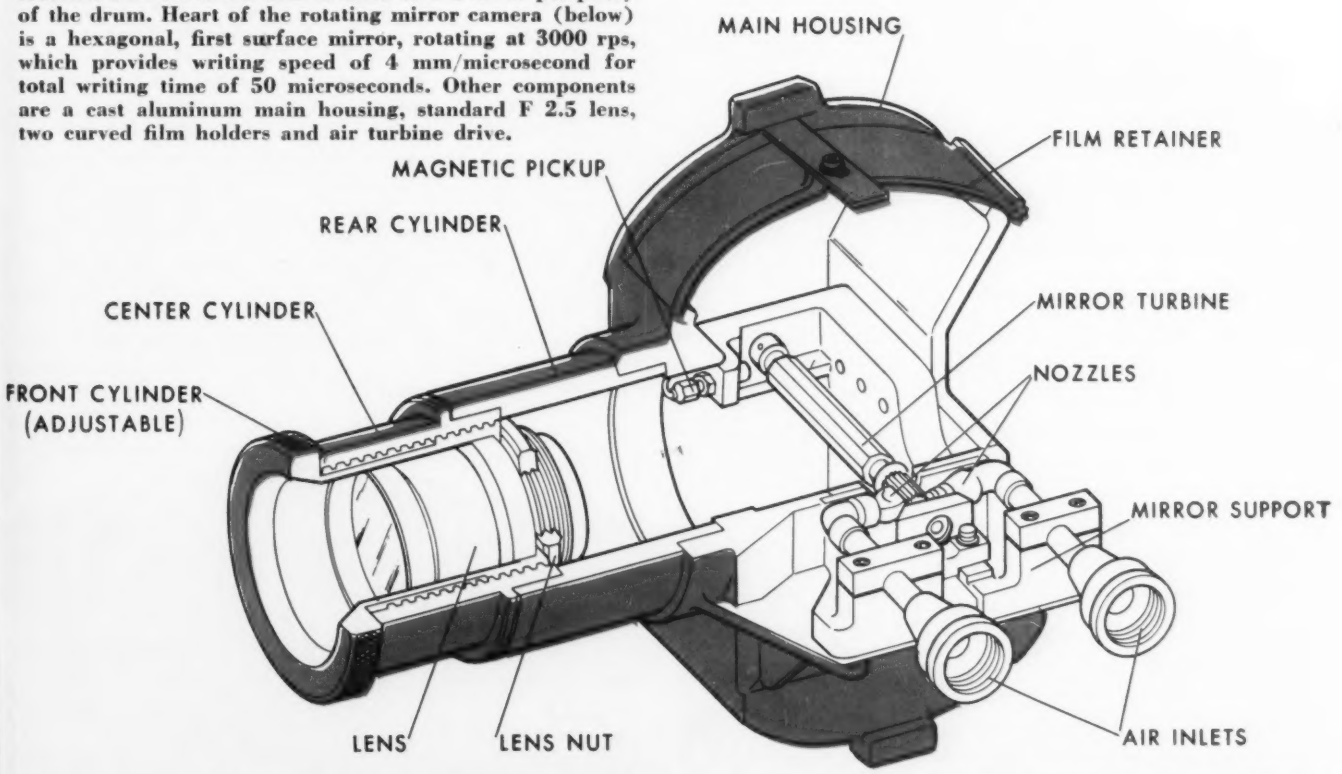
Drum-camera record of shock tube phenomena showing shock waves around missile model.

Close-up of missile model in shock tube experiment showing shock wave—taken with drum camera.

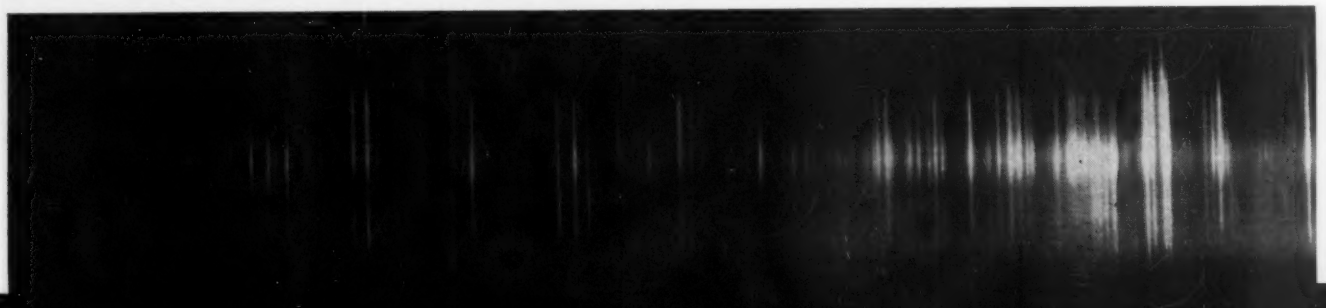




In rotating drum camera (above) dynamically-balanced drum rotates at 600 rps for a writing speed of 0.19 mm/microsecond and total writing time of 1667 microseconds. Fast emulsion film is fixed to the inner periphery of the drum. Heart of the rotating mirror camera (below) is a hexagonal, first surface mirror, rotating at 3000 rps, which provides writing speed of 4 mm/microsecond for total writing time of 50 microseconds. Other components are a cast aluminum main housing, standard F 2.5 lens, two curved film holders and air turbine drive.



Mirror-camera photograph of shock tube phenomena using spectrograph to record variation in spectral intensity with time.



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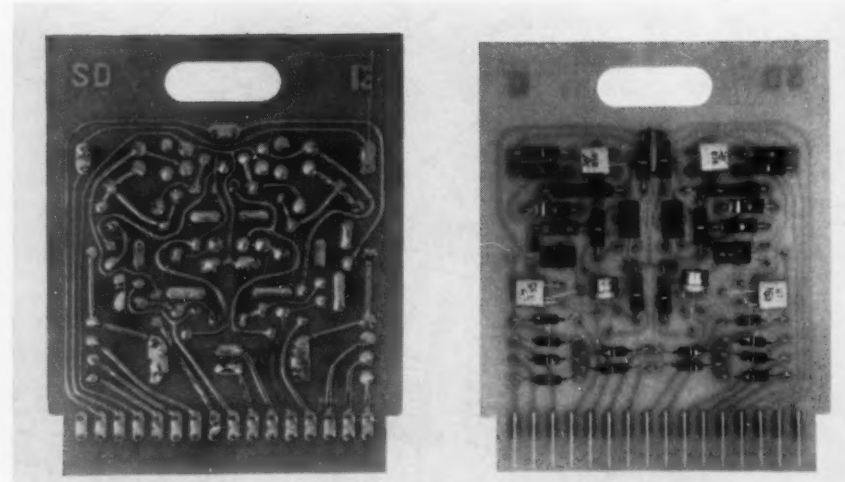


Front and rear views of typical glass-epoxy circuit module illustrate construction techniques. Note the Elco connectors along lower edge of right-hand view.

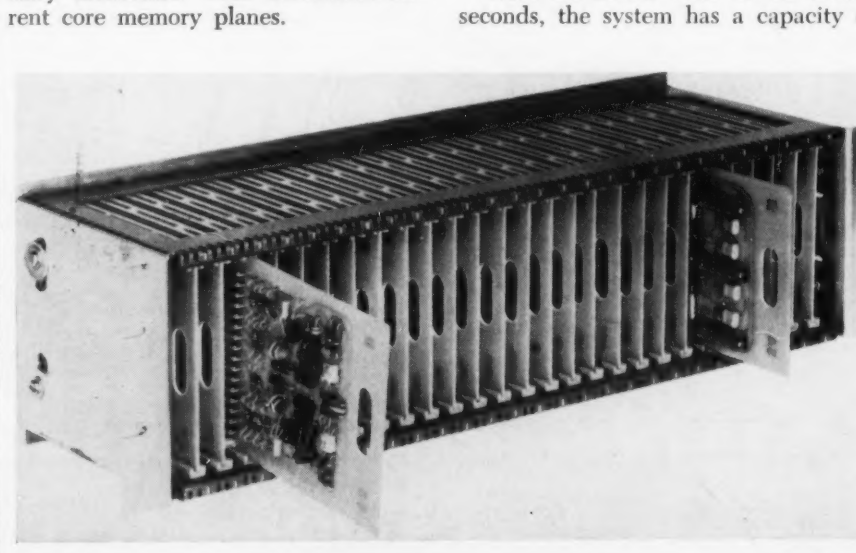
RANDOM ACCESS MEMORY SYSTEM

Standard Apertured Ferrite Memory Plate As a Storage Medium

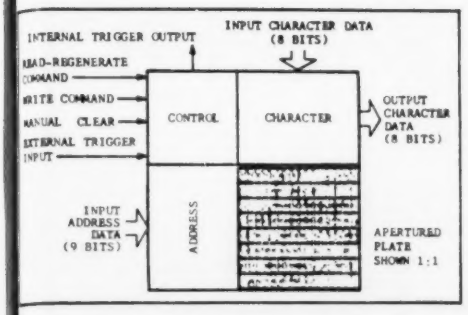
Using solid state circuitry throughout, Rese Engineering, Inc., of Philadelphia, Penn., has developed the first commercially available memory system to use the efficient RCA standard apertured ferrite memory plate for the storage medium. A topological technique developed at Rese results in an output signal to noise ratio of the plate read-out signals comparable to that usually associated with coincident-current core memory planes.

Dual advantages of low access drive current and high plate-stores reliability have been incorporated in the design which is based on conservative computer design practices using a minimum number of active circuit elements. All logic, power supplies, current switching and signal amplification in the memory system are transistor operated, and mount on etched, glass-epoxy plug-in modules which use reliable Elco contacts. Diodes and transistors are derated to conform to reliable computer end-point operation.

With an access time of 12 microseconds, the system has a capacity of



Modular construction permits application versatility; this is a standard, 27 board assembly.



Simplified block diagram shows standard apertured ferrite memory plate used as the storage medium in a random access memory system.

512 eight binary digit characters, with random access for both writing and reading. Read and write access cycles may be arbitrarily mixed, and synchronous internal timing, or synchronous or asynchronous external timing may be employed depending on requirements.

Self-contained in a 30″ rack cabinet, the system requires no supplemental cooling through the operating temperature range of 65F to 105F. Plug connectors at the rear of the unit provide for input and output connections. Front panel hardware controls a-c power, operating mode selection, internal clock frequency, manual clear, cycle initiation, and manual stop. Front panel indicators show the contents of a given address.

Modular construction permits expansion in both storage capacity and word length to fit particular applications. Standard parity circuits can check memory input and output data. For added functional flexibility, the character register may alternatively be a shifting register to accommodate input and/or output characters in serial form and to provide conversion between serial and parallel forms. Also, the address register may be converted to a binary or decimal counter that may cycle continuously or cycle to a present count. A signal indicating maximum count can be provided. For particular applications the counter can serve as a reversible device for counting up or down.

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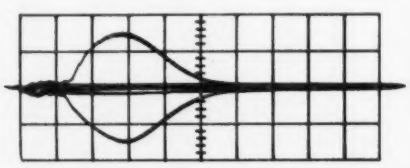

Oscillogram of apertured plate memory output shows ones and zeros.

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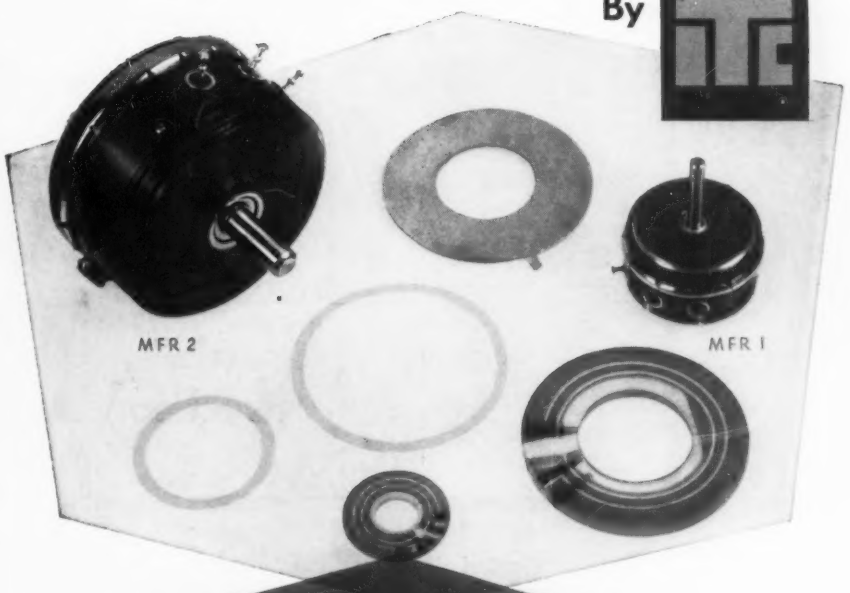
By TC



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A patented compression contact eliminates the wear or friction caused by usual wiper contacts. A precious metal capsule contact provides dependable long life operation. The deposited metal film resistance element is encased and hermetically sealed. The ultimate in craftsmanship is employed in the manufacture to produce a potentiometer unparalleled for performance. This new concept of design makes possible super reliability under the most severe environmental conditions such as those encountered in airborne, missile and satellite applications.

Details will be sent upon request.

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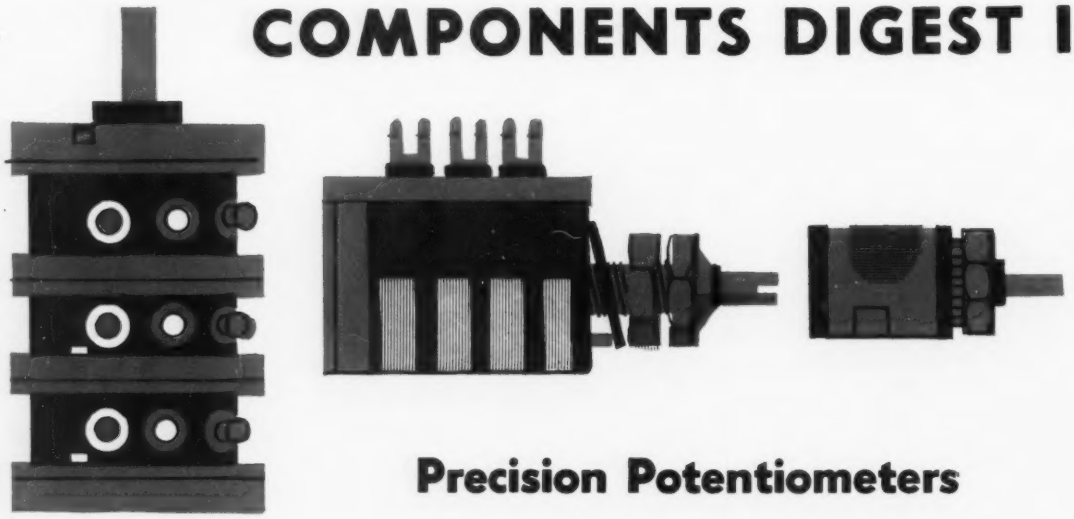
COMPONENTS DIGEST II



Precision Potentiometers

Potentiometers are electromechanical devices that develop an electrical output signal proportional to the product of an input electrical signal and some function of shaft angle. In the special but highly important case where the function of shaft angle is a straight line, a potentiometer is called linear.

Potentiometers have become so important in fields of computation and automatic control that a wide variety of more or less "standard" types has been developed, each with its distinct area of application. In addition, manufacturers are prepared to design "specials" to customers' specifications where existing types are not suitable. Thus, the user is faced with the formidable task of choosing from a great assortment of standard and special types, the one most suitable for his system. And since the potentiometer chosen often spells the difference between a workable and unworkable system, or between a complex and greatly simplified one, selection procedure is important.

The object of this Components Digest is to survey the current state of the art in precision potentiometers. Emphasis is on resistance potentiometers used in computers and automatic control systems, rather than on laboratory types. Potentiometer performance and selection factors are described in detail. Included are important standards (incomplete as they are) and a summary of future performance and environmental characteristics anticipated by the industry. A Master chart presents the performance characteristics of potentiometers available from leading manufacturers, in a uniform and concise presentation. A buyer's guide and a pertinent bibliography close the section.

Varieties of Potentiometers

To suit diverse requirements, a variety of more or less specialized potentiometer types has been developed. Magnetic devices such as the induction potentiometer and the differential transformer offer significant competition to the straight resistance potentiometer. Less well known types such as the dielectric potentiometer, the capacitive potentiometer, and others are well suited to certain special requirements. However, since the scope of application of these devices is minor compared with that of resistance potentiometers, we have limited the survey to resistance units to permit more detailed coverage.

Even here, however, a great variety of types is available. Table I lists the more important of these types briefly describing their features and recommended applications. In potentiometer selection, Table I is useful as a first step in determining which type is most suitable before detailed specifications are considered.

The major portion of the Digest, including Tables II, III, and IV, and Summary Performance Charts CD-II, covers wire-wound pots, by far the principal type in use today. Tables V, VI and VII cover film pots, designed for zero resolution and high temperature operation. A brief section, including Tables VIII and IX is added on trimming pots because of their widespread use.

Nonlinear Potentiometers

Among important features of resistance potentiometers is the ease with which they can be adapted to generation of nonlinear functions. A number of common generation techniques are available, the choice of which depends upon nonlinearities to be generated and type of potentiometer.

TABLE I

VARIETIES OF RESISTANCE POTENTIOMETERS

SINGLE-TURN	LIQUID FILLED (for a variety of mechanical and environmental advantages)(2)
MULTI-TURN	
LINEAR MOTION	
CARBON FILM	COMBINATIONS OF TYPES, notably semi-digital types where switching is combined with linear interpolation for very high accuracies in a compact unit.
METAL FILM	
CONDUCTING PLASTIC	
TRIMMERS	
NONLINEAR TYPES	
SLIDE-WIRE (for high resolution)	ULTRA-LOW TORQUE (to a few thousandths of an oz-in)(1)

For further information on varieties of potentiometers, consult Reference 5.

(1) For example, consult Electro-Mec., Giannini

(2) For example, consult Helipot.

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from ½" to 5"

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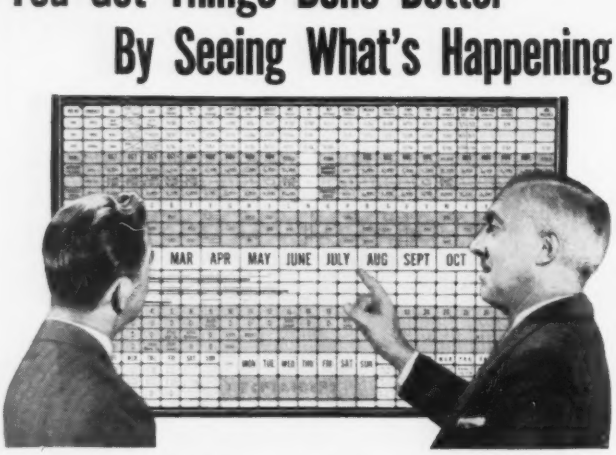

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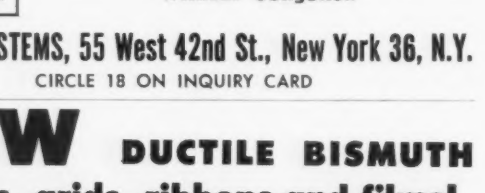

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PRECISION POTENTIOMETERS (Cont.)

Since the types of conveniently generated nonlinearities and the accuracy and ease of manufacture depend upon the nonlinearizing technique, Table II is designed to show the application engineer how potentiometers generate nonlinear functions and how to choose the design best suited to his needs.

Potentiometer Selection Factors

Intelligent selection of a precision resistance potentiometer, and preparation of an adequate procurement specification for the selected unit calls for a clear picture of the non-ideal factors that characterize its performance. Table III lists and defines these non-ideal factors. In addition, a great variety of more or less obvious selection factors must be specified. These are listed without special description in Summary Performance Charts CD-II toward the end of this survey, which tabulate a great many potentiometer performance specifications. Definitions listed under Potentiometer Standards provide valuable insight into selection factors.

Environmental Problems and Wear

Current trends in military equipment have imposed severe environmental requirements on potentiometer manufacturers. Meeting extreme environmental requirements with little degradation of performance requires the best in mechanical design, specifications of materials, manufacturing plant processing and quality control. Helipot summarizes the effects of environmental extremes in Table IV, from Ref. 1, which describes important environmental effects on precision potentiometer performance. The status of current environmental limits is described elsewhere in this Digest.

Helipot, in Ref 1, describes the indicated trends in potentiometer construction to meet severe environments. These are: "a miniaturized design, using a metal housing designed to give good heat conductivity to the mounting surfaces; all insulation of nonhygroscopic, high-temperature material of Class H or higher; spring materials in the heat-treated stainless category; all electrical contact surfaces of noble metal alloys; all stationary electrical connections to be welded or soldered; close match of the expansion of resistance wire and mandrel; stainless steel precision miniature ball bearings spring loaded; sealed construction with well-designed clearances and creepage paths, both inside and out." They add, however:

"As the requirements become more severe, design approaches radically different from those used in today's potentiometer design will have to be instituted."

Wear due to motion of the slider on the resistance element is an important factor in life and reliability of precision pots. In the following paragraphs taken from Reference 2, Helipot describes how wear affects operating characteristics. "Contact wear increases with increasing contact force and increasing temperature. It can be minimized by proper engineering of the coil-and-contact system, which takes into consideration:

WIRE ALLOY	RESISTANCE-ELEMENT LENGTH
WIRE SIZE	CONTACT ALLOY
WINDING PITCH	CONTACT-SPRING DESIGN

In any potentiometer, the contact should be soft enough to prevent undue wear of the resistance element, but not so soft as to abrade and contribute noise-producing particles, or so soft as to limit the potentiometer's life. For the same wire alloy and size, the contact alloy may change for different resistance-element lengths. For example, in a multi-turn potentiometer with an element 400 inches long, the contact should be harder and more wear-resistant than

in a single-turn unit with an element only four inches long.

"Wear of a sliding contact carrying current is not due to mechanical abrasion alone. The sliding contact of a potentiometer shorts two or more turns of wire on the resistance element. A large portion of the coil current flows into the contact and back into the coil. This current is continually interrupted as the contact moves along the element, resulting in electrical or arc erosion of the contact.

"Contrary to popular belief, coil current, rather than load current, is responsible for the effect; because, to minimize loading error, load current in a potentiometer is usually held to no more than 1 percent of coil current. *Cont'd. pg. 32*

TABLE II

WIRE WOUND NONLINEAR POTENTIOMETERS

Very often, an application requires that a potentiometer generate a nonlinear voltage function of shaft rotation. Potentiometers for this purpose are called nonlinear. A great variety of nonlinear potentiometers are available. Some are rather general in their construction, permitting development of many types of nonlinear functions by a routine process of modifying the resistance element. Others are suitable only to particular nonlinear functions, especially the sine-cosine functions.

In specifying a nonlinear potentiometer, an engineer must appreciate that accuracy and resolution will generally be poorer than in linear potentiometers of approximately the same size, except perhaps for film-type units. Resolution will vary depending upon the point or region of nonlinearity under consideration. Ratio of the maximum to the minimum slope of the nonlinear function is an important parameter in deciding how difficult the nonlinear function is to generate. That is, where maximum to minimum slopes are very high, attaining accuracy at reasonable cost is difficult. Sometimes, when the functions are especially difficult to generate, employing some combination of the commonly used nonlinear techniques is necessary to achieve the required overall performance. Maximum practical slope ratio for a nonlinear resistance potentiometer employing a resistance element wound on a card is approximately 5:1, because the turns of resistance wire slip out of position when this ratio is exceeded.

This table lists the common types of nonlinearizing techniques. Combinations of these are often employed and selection of the optimum method must be decided by consultation with the manufacturer.

TECHNIQUES FOR NONLINEARIZING

- Varying wire spacing.
- Varying wire size. Shorting out a portion of the resistance element provides a zero slope where required.
- Winding on a card of variable width. A stepped card is a special case.
- Tapping and shunting portions of the resistance element. Exciting a tapped potentiometer from a tapped transformer also may provide a nonlinear function.
- Loading the potentiometer, special networks of resistors (and perhaps amplifiers) developing specialized functions. A wealth of literature exists on the generation of nonlinear functions in this manner. Special purpose circuits are described for tangent, logarithmic, and other functions.
- Special purpose techniques such as using a wound flat card with a slider describing a circle on the flat surface to generate sinusoidal functions.
- Ganging potentiometers, operating them in cascade, useful for power law functions.
- In film-type potentiometers, adjusting the film contours for a desired nonlinearity.

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TABLE III

PRECISION WIRE WOUND POTENTIOMETER PERFORMANCE FACTORS

FREQUENCY CHARACTERISTICS[1]

From direct current up to operating frequencies of approximately 400 cps, the Kohlrausch wound resistance element of a pot acts as a pure resistive load. At higher frequencies, the distributed inductance and capacitance plus the winding resistance assume a complex characteristic. An inductive effect is produced by many turns of wire on the metal mandrel. Capacitive effects arise from turn-to-turn of the winding, turn-to-turn of the helix, and between these and other parts of the unit, particularly the copper mandrel. The resistance element supplies the resistance parameter of a total and complex transmission line with R, L, and C distributed throughout its length.

A lumped-parameter circuit drawing is worth little more than a visual demonstration of a potentiometer's approximate electrical character. Nor can the several parameters be analyzed and evaluated. How a potentiometer will respond under given conditions of a-c excitation can be determined reliably only from actual measurements made upon the unit in question under required excitation conditions.

The a-c characteristic curve shown in Fig III(a) depicts how impedance variations are affected by total resistance in three-turn potentiometers. In applications where frequency characteristics must be weighed, this curve will assist in choosing optimum values.

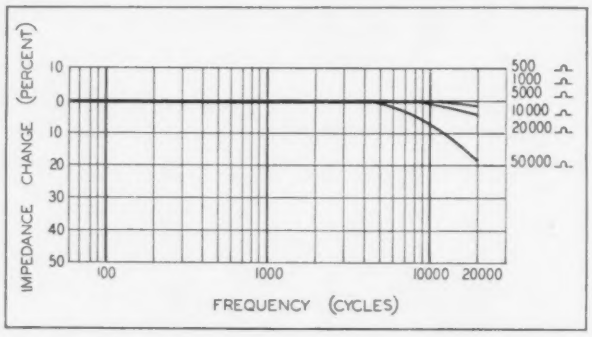

Fig III(a)—A-C characteristic curve for a three-turn Borg pot.

Reference 3 discusses this subject in great detail, suggesting methods of compensation. Reference 9 shows how to compensate for capacitor loading by padding capacitors placed across appropriate potentiometer taps.

NOISE[1]

Two types of noise may be encountered in a wire-wound potentiometer; vibrational or microphonic noise, and residual noises from several sources. Vibrational noise, while in effect electrical, is purely mechanical in cause. It is produced by the contact jumping away from the winding and thereby opening the contact circuit. Proper design of the contact arms, carefully calculated pressures, and close control of all structural resonanaces, will practically eliminate this class of noise. Avoidance of coarse winding will reduce "bounce" and correspondingly raise the optimum operational velocity of a given pot without generating vibrational disturbances. Resolution noise is a stepping voltage variation introduced by the contact transit across discrete turns of resistance wire, and is inversely proportional to the resolution figure of a given pot. There are, however, residual noise effects which consist of sharp random voltage peaks generated between the moving contact surface and winding.

The principle cause of residual noise is foreign material; ie., dirty windings, wear products, etc., which intrude between contact surface and winding. Contact resistance fluctuations arising from such contamination are characteristically large, relatively stationary with respect to time, and independent of slider velocities.

The foregoing noise effects may be properly termed "passive". This type of noise is guarded against by foresighted design, scrupulously clean working conditions, and judicious use of long-wearing and electromechanically compatible wire and contact materials. Units should be carefully checked for contamination and assembled in dust-free, air-conditioned rooms.

Sources of "active" residual noise are not so simply analyzed. Fortunately, the resultant electrical disturbance in wirewound pots rarely exceeds, voltage-wise, a small fraction of a millivolt. Active noise is self-generated voltage under three principle sets of conditions; galvanic or chemical action at the point of contact between slider and wiper; thermoconjunctive effects, which depend on frictional or external heat; and triboelectrical phenomena, small voltages generated by abrasion of the contact upon the wire. Here again, noise is minimized by use of compatible materials, proven welding techniques, and optimum contact pressures.

Noise tolerances are most commonly expressed as an equivalent resistance. Some users appraise noise voltage-wise. In either case, unless otherwise specifically noted, evaluations of noise are made with a constant current of one ma. This noise figure is, in brief, a quantitative measurement of the total residual and microphonic noise, and is defined as the total residual noise peak voltage divided by the source current, the source current and actuator velocity always being specified. The several types of potentiometer noise discussed here may be summarized with regard to origin and possible modes of expression:[2]

Noise Type	Origin	Expression (Noise Figure)
Loading Noise	Load current flowing through fluctuating contact resistance.	Ohms (peak-to-peak variation in contact resistance).
Shorting Noise	Winding current flowing through fluctuating contact resistance.	Equivalent ohms peak-to-peak (calculated from an observed winding current and noise voltage).
Resolution Noise (due to winding current)	Stepped nature of wire-wound resistance element.	Per cent. (riciprocal of number of turns of resistance wire).
Resolution Noise (due to load current)	Stepped nature of wire-wound resistance element.	Ohms (resistance per turn of resistance wire).
Generated Noise	Tribo effect.	Millivolts or microvolts.
High Velocity Noise	Brush leaving winding above critical velocity.	In terms of pulse width and critical velocity.

POTENTIOMETER LOADING

Loading a precision potentiometer, by drawing current from its wiper, affects the output voltage versus rotation characteristic by an amount depending upon degree of loading and angular setting. Potentiometer loading may be intentionally introduced to develop a required nonlinearity, or it may occur as a natural consequence of its application circuitry. Generation of a desired nonlinearity by loading is described earlier in this Digest. In the simplest case, a linear potentiometer having a resistance R is loaded by a resistor from one terminal to its wiper having a resistance of kR, where k is generally much greater than one. Nature of the loading error as a function of

Footnotes:

1. Derived from Ref. 4. 2. Derived from Ref. 7.

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Table III (Cont.)

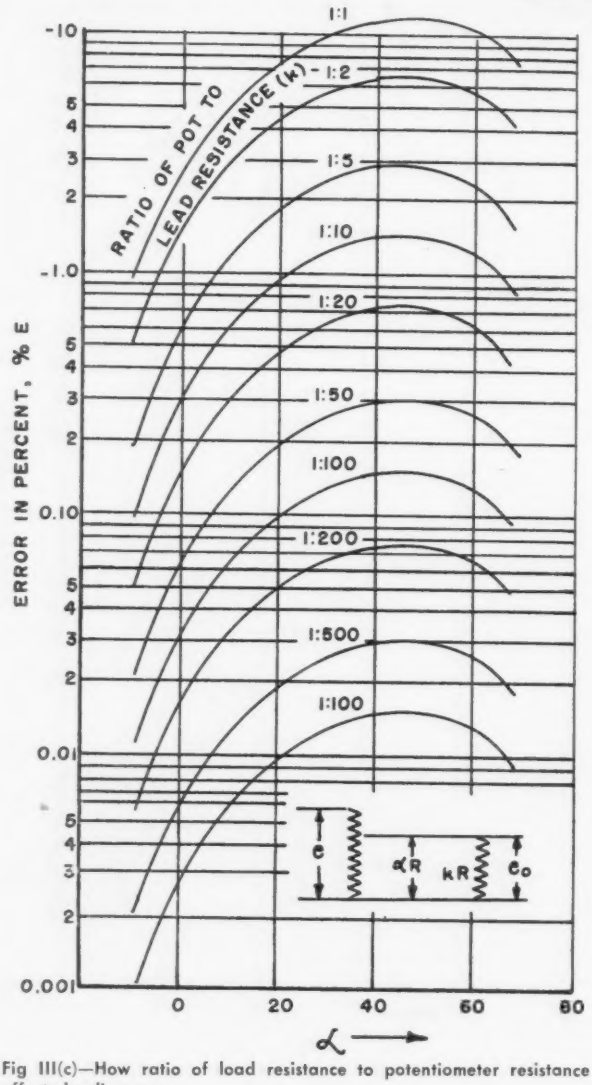


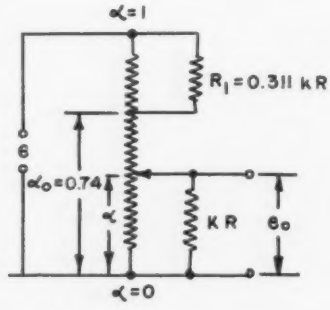
Fig III(c)—How ratio of load resistance to potentiometer resistance affects loading error.

shaft rotation is shown in Fig III(c). Generally it is desirable for k to be ten or more in high accuracy circuits. Because potentiometer circuitry is confined to a limited range of impedance, restricted by resolution and power dissipation on the low extreme, and stray inductive and capacitive effects on the high extreme, it is not always feasible to use a k greater than 10 when a succession of potentiometers is cascaded. In this instance one of several methods of load compensation may be applied:

- Introduce a slight nonlinearity in the potentiometer characteristic to compensate for loading error. When the application circuit is known sufficiently in advance, and quantity justifies the small special tooling expense, this particular compensation technique may be most suitable.
- Pad resistors across fixed tap points. If a tap be provided at approximately 74 percent of the potentiometer electrical angle from the common potentiometer-load resistor terminal, and a padding resistor of 31.1 percent of the load resistor is connected from the tap to the remaining potentiometer terminal, the maximum nonlinearity error will be 1.9 percent. Table III(a) shows the one tap and two tap compensations. Ref 8 shows the extension to as many as 5 taps, and provides all proofs and derivations. The advantage of this type load compensation is its flexibility; it is adaptable to a range of load resistance ratios, and therefore suitable for many applications. Similarly, compensating for phase shifts due to capacitor loading (stray capacitance in wiring, or in potentiometer itself) by using padding capacitors across the tap points is also practical (See Ref 9).
- Use isolation amplifiers where feasible to eliminate loading.
- Where two potentiometers are balancing against one another, eliminate errors by loading the pots similarly.
- Restrict range. The potentiometer output can be limited to a fraction of the input by means of appropriate dropping resistors in series with each of the potentiometer fixed terminals. This, in effect, is comparable to a potentiometer having a higher total resistance and wide angular range, only a limited portion of which provides effective rotation. For a k = 10, a loading error reduction of almost 5 to 1 is feasible (See Ref 10.).

RESOLUTION CHARACTERISTICS

Resolution in a wire-wound resistance potentiometer is due to the stepwise voltage variations occuring as the slide moves across discreet turns of the resistance winding. Resolution is measured as the reciprocal of the total number of turns in the resistance



Nomenclature
R=potentiometer resistance
kR=load resistance
R_1=compensating resistor
α_0=tap location of compensating resistor
α=wiper location
e=input voltage to potentiometer circuit
e_0=output voltage

Fig III(b)—Loaded linear pot with one-tap compensation.

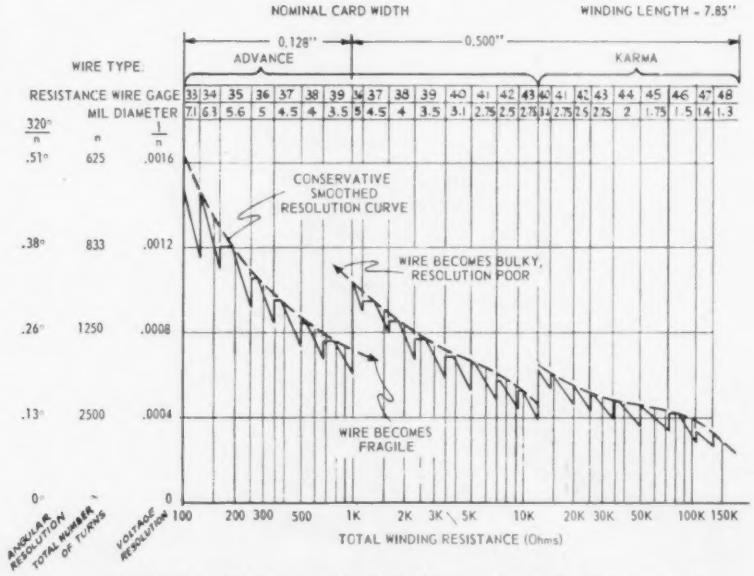


Fig III(d)—Resolution vs. total winding resistance for optimum wire sizes in a 3-inch diameter wound-card potentiometer.

continued on next page

Table III (Cont.)

element. In the usual case where the slider simultaneously contacts two or more wires, resolution phenomenon is more complex (see Ref. 6, page 6-3).

Important relationships exist between values of achievable resolution and total winding resistance of the potentiometer. The factors include dimensions and resistivity of the resistance wire, size of card or mandrel, number of turns required to achieve the desired total resistance, and resultant spacing of successive turns of the winding. Wire size is limited on one extreme by fineness that can be wound without damage, and with an adequate expected life, and on the other hand, by the bulk, which results in poor resolution. As resistance is increased, finer wire is used, and resolution improves. When the limit of fineness is reached, a grade of material having a higher resistivity is required resulting in a heavier wire with poorer resolution. The figures below show variation of resolution with total winding resistance for the specific case of a 3 inch diameter single-turn potentiometer, and for a general case. Width of card is varied in the first instance as indicated.

Table IIIb lists properties of common resistance material as tabulated by George Rattray and Co.

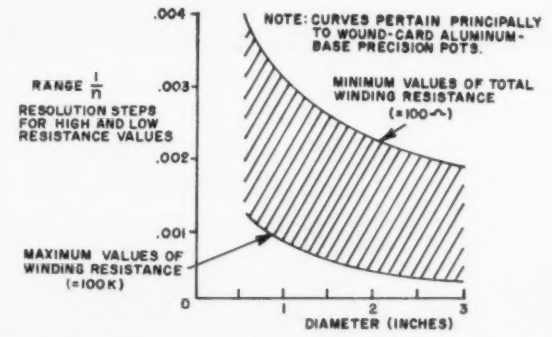


Fig III(e)—Trend in 1/n resolution limits with increase in potentiometer diameter[3].

Footnote:
3 Courtesy of Technology Instrument Corp.

TABLE III (a)

SUMMARY OF FINAL DESIGN PARAMETERS

	Tap Location	Shunt Resistor Values	k times Maximum Error
ONE TAP	$a_1 = 0.74$	$k > 10$ $R_1 = 0.311kR$	1.9 percent
TWO TAPS	$a_1 = 0.20$ $a_2 = 0.80$	$k = 20$ $R_1 = 0.66kR$ $R_2 = 0.66kR$	0.5 percent

TABLE III (b)

COMMON RESISTANCE WIRE MATERIALS

Resistivity Ω/CMF	Nominal Temp. Coeff. of Resistance (20-100°C)	Trade Name	Manufacturer
800	±.00002	Karma	Driver-Harris
800	±.00002	Evanohm	W. B. Driver
550	+.00002	L.T.C.	Sigmund Cohn
650	+.00011	Nichrome V	Driver-Harris
650	+.0001	Tophet A	W. B. Driver
294	±.00002	Advance	Driver-Harris
294	±.00004	Cupron	W. B. Driver
400	+.00024 Max.	Alloy #479	Sigmund Cohn
180	+.0006 Max.	Alloy #851	Sigmund Cohn
80	+.00067	Ney-Oro G	J. M. Ney

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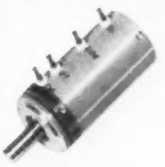
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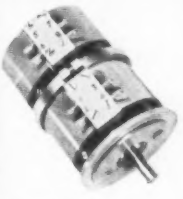
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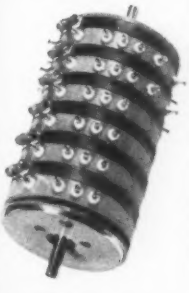
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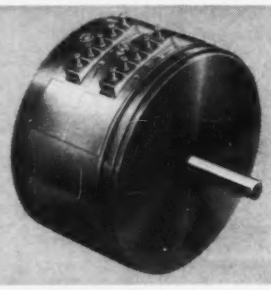

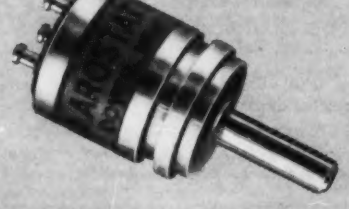

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- **Choice of continuous or limited rotation.**
- **Rugged construction electrically and mechanically.**

Multi-turn adjustment of resistance for greater accuracy in effect and readout...

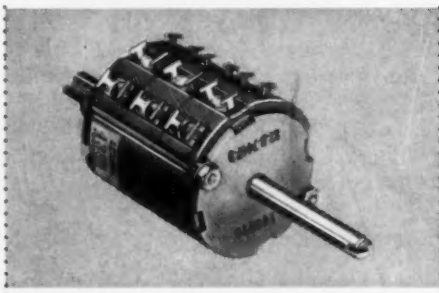
- **Greatest winding length in given outside diameter.**
- **Maximum immunity to environmental conditions.**

Padding or trimming effect in minimum space, under adverse environmental conditions.

- **Rugged mechanical and electrical construction.**
- **Low-temperature coefficient wire.**
- **Positive clutching and de-clutching mechanism.**

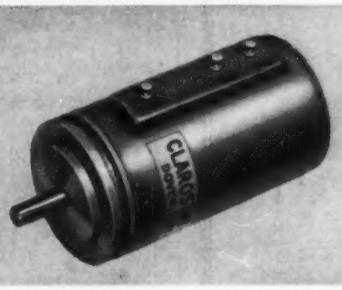
INTELLIGENCE QUOTIENT IS O. K.!

CLAROSTAT SERIES 42 PRECISION POTENTIOMETER



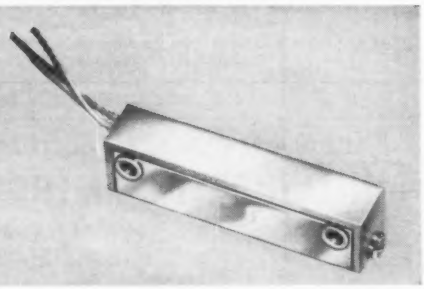
A highly versatile precision potentiometer offering a choice of continuous or limited rotation. Individual units are encased in a high dielectric phenolic and ganged by means of threaded rods and metal end-plates. Electrical rotation is 291° plus/minus 3%. The Series 42 exceeds MIL-R-19 specifications where applicable. 3-watt power handling capacity, with linear resistance range of from 1 to 100K ohms, and a tapered range up to 350 ohms per degree of rotation. Resistance tolerance is plus/minus 5%.

CLAROSTAT MULTI-TURN PRECISION POTENTIOMETER



A superior material, electrically and mechanically, is used for the housing, making possible a thinner shell which in turn provides up to 20% more winding length for given outside diameter. This means a greater overall resistance range and finer resistance resolution, size for size, than other comparable units. Available in three sizes from .875" to 2" dia., and from 3- to 6-watt ratings, with resistance ranges depending upon size selected. All units are 10-turn, with 5% resistance tolerance standard, 1% special.

CLAROSTAT PADOHM® PRECISION POTENTIOMETER



A 25-turn rectangular precision potentiometer built to the highest standards of design and materials. A low-temperature coefficient wire is wound on a special ceramic core for maximum stability. Effective electrical travel is 98% minimum of mechanical travel. End resistance is 1% of maximum overall resistance. Available in two types: 1.25 watt and 0.25 watt, derated to "0" power linearly at 135° and 105° C. respectively. Resistance range of from 100 to 20K ohms employing plus/minus 20 ppm wire standard.

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CLAROSTAT MFG. CO., INC.

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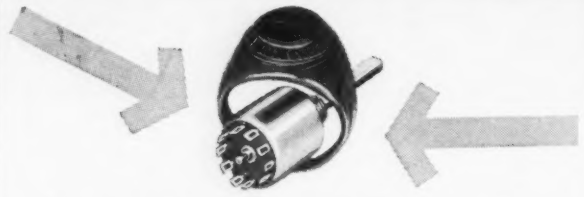
CIRCLE 19 ON INQUIRY CARD



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Daven's New Series G Sub-Miniature Switch, 1/2" Diameter!

A new sub-miniature rotary selector switch, developed by DAVEN, is specifically suited for application in missiles, aircraft, handy talkies, field pack sets, frog-man communication equipment, and all types of mobile apparatus. This explosion-proof, waterproof switch has the same reliability as its bigger brothers...but in a fraction of the space. It meets applicable military specifications on temperature, humidity, corrosion, vibration, acceleration, shock and immersion.

This unit is available as a single pole, 10 position switch and can be obtained with up to four poles on a single deck.

THE DAVEN CO.
LIVINGSTON, NEW JERSEY

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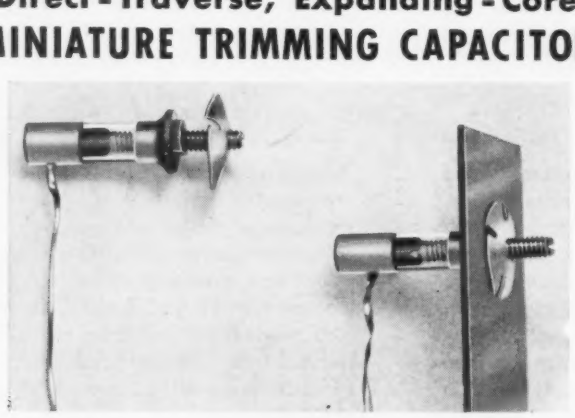
Direct-Traverse, Expanding-Core MINIATURE TRIMMING CAPACITOR



Illustrated same size — Patented

Designed for the coming space age, the ATLEE Variable Capacitor operates on new electro-mechanical principles to give a much greater range and higher stability with less space and weight than ever before.

Only 25/32" long and 3/16" in diameter, its capacitance range is 0.5 to 5.0 mmf. Has micrometer adjustment. Available in glass dielectric and brass for standard panel mounting or quartz and invar for special applications.

A rugged unit, it will maintain a set value under extreme vibration and shock *without undue stress!* Has excellent retrace characteristics. Full-floating piston assures positive mechanical alignment, eliminating run-out.

ATLAS E-E CORPORATION

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CIRCLE 25 ON INQUIRY CARD

PRECISION POTENTIOMETERS (Cont.)

"Externally excited vibrations may produce wear by causing contact movement, not readily observable, at right angles to the resistance element as well as along the element. The amplitude of this movement is small; but, if continued for appreciable time at moderate frequencies, the total travel is great.

"A similar source of wear seldom considered by the user may exist in servo systems, when oscillatory motion is induced by 'hunting.'

"The potentiometer manufacturer can minimize the effects of external vibrations by appropriate contact-spring design, and by employing axial spring-loading of ball bearings to eliminate bearing play, which will reduce relative motion between the coil and the rotor (to which the contact is attached).

"He can also minimize many factors which cause coil-and-contact wear by designing his product for oil immersion. Some of the benefits thus realized are reduction in arc erosion, rate of mechanical abrasion and oxidation of resistance wire; increased power dissipation; flushing of worn particles from the resistance element; damping of contact-spring vibrations whether internally or externally excited."

Principal effects of wear are:

(1) *Change in total resistance due to reduction in cross-section of resistance wire, by shorting of wires either through mechanical displacement, or the shunting effect of abraded particles between the wires.*

(2) *Change in linearity due to factors in (1) above, as well as some bearing wear causing mechanical eccentricity.*

(3) *Noise, which is affected most and is the most unpredictable. Abraded particles, dust and oxidation of contact surfaces, contribute to noise.*

Multi-Turn Potentiometers

Advantages—Ten-turn potentiometers are inherently capable of delivering better accuracies and resolution than single-turn units. Gain in quality is not in the same ratio as the number of turns, however, since many of the geometric errors become difficult to control in the more complex multi-turn structure. Such errors as eccentricity of the wiper and the coils of the resistance element and ellipticity in the shape of the resistance element are diminished in proportion to the total number of potentiometer turns for given manufacturing tolerances. Errors from these sources appear as periodic variation over the angular travel of the potentiometer, repeating for successive turns. All in all, for a given size, especially where small diameter is to be desired, the multi-turn potentiometer is markedly better than the single-turn unit.

Thus, the principal advantage of the multi-turn potentiometer is greater accuracy in miniature size. Subsidiary advantages include much finer resolution for a given size of resistance element wire (roughly, resolution improves proportionally to total angular travel), achievement of much higher resistance values where required, large total angular travel requiring much less precision in the gearing and associated mechanical hardware, less critical installation, since mechanical mounting tolerances may be reduced, ease of shaft zeroing due to large angular range, improved stability of performance, and much closer tolerances percentage wise on total angular travel. For example total electrical angle for a typical 10-turn pot is defined as 3600 +2 −0 degrees, a total spread of one part in 1800, or 0.055 percent. This simplifies or even may eliminate the

need for trimming in many applications. Similarly, the location of taps within ±1 degree roughly corresponds in accuracy to a ±0.1 degree location accuracy in single-turn units, an extremely tight requirement.

In many applications, the multi-turn unit provides improved reliability, with its use of heavier wire for a given resolution and resistance requirement. Heat generated in a multi-turn unit is distributed over a much longer resistance element, providing greater thermal capacity through increased heat transfer surface areas, and better contact to the housing, with a diminution of hot spots.

The higher spread of the multi-turn potentiometer results in much lower motor torques on the shaft, and much less strain of possible impact on the limit stops. This acts as an important safety element to the mechanical portion of gear reduction servos.

Disadvantages. Certain limitations and disadvantages to the multiturn unit should be considered to avoid possible misapplication.

For example, the multi-turn unit is not as suitable for lower resistance values. It is not as readily adaptable to generation of nonlinear functions, except through use of external shunt resistors.

In some applications where it is desirable to avoid gearing, the single turn potentiometer is more sensitive to small mechanical inputs. This is especially true where a sensitive transducer provides an output displacement to directly actuate a precise resistance potentiometer.

When a servomechanism has a duty cycle requiring frequent slewing, or operation with rapidly changing inputs, the slider of the multi-turn potentiometer must go much faster, resulting in increased noise, wear of the slider and eventual reduction in life.

The gearing problem for a multi-turn potentiometer may be somewhat more complex because of need for a separate potentiometer shaft drive, and requirement of a nearly exact ratio between potentiometer and load.

It should not be inferred that because a multi-turn potentiometer can be made to very high resistance values, loading problems can be handled simply by specifying indefinitely higher resistances in consecutive stages of a potentiometer chain. In high resistance circuits, particularly at 400 cps and higher frequencies, errors due to stray capacitance, both within and external to the potentiometer became pronounced. These result in phase-shifts, and quadrature voltages, which seriously impair the operation of precision servomechanism loops.

The above information on multiturn pots was based on information provided by Technology Instrument Corp.

Film Type Potentiometers

Film type potentiometers merit separate consideration. They offer promise in applications requiring high resolution, high operating temperatures and sometimes where excellent accuracy is required in small size. Among the companies offering precision film type potentiometers are Computer Instruments Corp., Servomechanisms, Inc., Technology Instrument Corp., Fairchild Controls Corp. and Elektro-Serv Co., listed in the Buyers' Guide section of the Digest.

Important film potentiometers are carbon film, metal film and plastic film types. They share the quality of high resolution, and suffer generally from similar application limitations as described below. Fig 1 compares the resolution of a T. I. C. film potentiometer and a similar wire-wound unit.

Carbon Film Potentiometers—Since Computer Instruments Corp. is the principal manufacturer of carbon film potentiometers, most of the information on these units has been obtained from that source.

Carbon-film precision potentiometers provide exceptional resolution, delivering a continuously varying stepless voltage. The smooth unbroken surface of the element permits high-speed operation and assures long life (1,000,000 cycles at rotational speeds up to 1000 rpm). Separately available carbon resistance elements are especially useful where the potentiometer must be built into a mechanical component (such as a gyro or accelerometer) because of space or available torque limitations.

By control of film properties—thickness, width and resistivity—very high linearities or nonlinear conformities may be achieved. By a contour milling technique, the carbon film may be "trimmed" with servo-control to achieve best accuracies. Carbon film permits a high degree of curvature in the nonlinear functions generated. Range of resistance possible with a film potentiometer is much greater than for comparable wire-wound types.

In effect, carbon film may be regarded as a surface across which a potential difference is applied. A family of orthogonal equipotential, current flow lines exist in the film, uniformly spaced for the linear case. The wiper serves as a pick-off indicating the potential at its contact point with the film. Wear, which occurs along a current flow line, does not disturb the field, nor impair accuracy. It does however manifest itself in an increasingly erratic output voltage, ultimately showing intermittent opens. Relocating the wiper path restores potentiometer output to its original quality. The very gradual deterioration in performance is an important reliability feature in equipment where a sudden failure, such as an open in the resistance element, could have serious consequences.

By its nature the carbon film potentiometer offers a flexibility not found in more conventional types. This is a consequence of the ease with which the "resolutionless" film may be deposited in narrow or irregular paths. One special type of step-function potentiometer yields its output in 3° of rotation approximately 100 times the sensitivity of the conventional one-turn potentiometer. A great variety of other specialized types, including units with built-in resistors formed out of the carbon film (to be used in conjunction with the potentiometer portion), pulse generators that provide as many as 36 complete approximately sinusoidal oscillations per shaft rotation, units with switching and commutation functions, and others, are available.

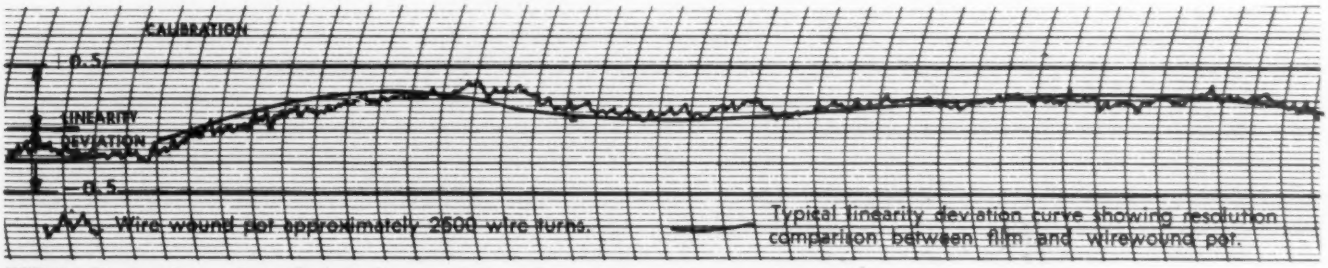
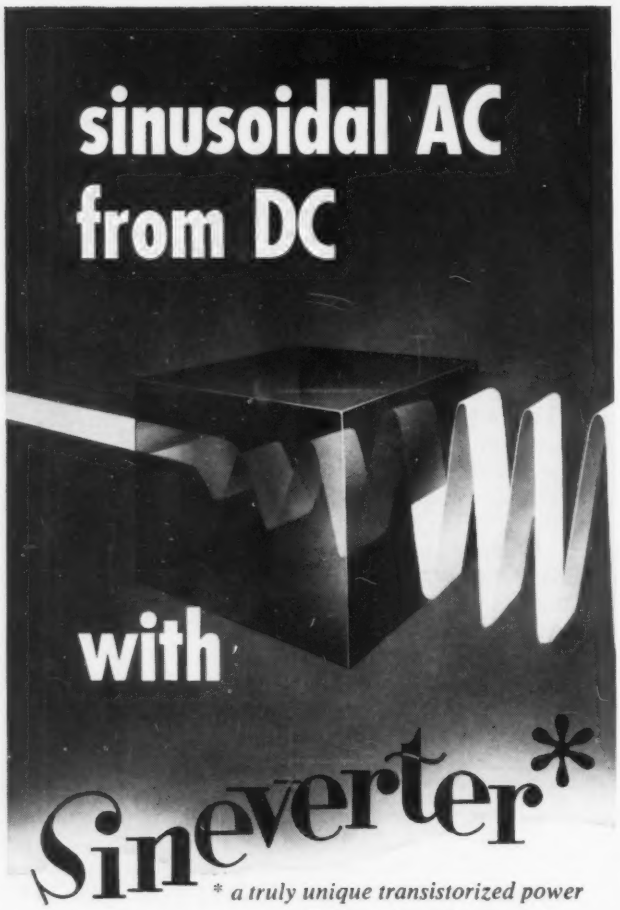


FIG 1—Comparison of resolution characteristics of precision wire-wound and film-type potentiometers.



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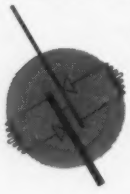
INPUT VOLTAGE:	**Up to 50 volts DC**
OUTPUT VOLTAGE:	**As required**
OUTPUT FREQUENCY:	**50 to 1500 cps as required**
TOTAL HARMONIC CONTENT:	**Normally less than 5%, 1% if desired**
REGULATION:	**±2% or less for normal line changes. 2% no load to full load.**
FREQUENCY STABILITY:	**Normally ±1%. To .001% if desired**
POWER OUTPUT:	**Up to 1 kva**

IMPORTANT: Sineverters are open- and short-circuit stable. In contrast with some inverters, a Sineverter cannot be damaged by open or short circuits and is immediately operative upon removal of an output short. . . . Yet output wave shape, voltage, and frequency are unaffected by load variations within ratings.



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BURLINGTON, MASSACHUSETTS

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TABLE IV

ENVIRONMENTAL EFFECTS ON PRECISION WIREWOUND POTENTIOMETERS

These Environments	Affect These Potentiometer Characteristics	Because of
High Temperature	Noise, Life	Oxidation of contacting surfaces, resin vapors, spring relaxation
	Resistance	Wire temperature coefficient and strain-gauge effect
	Torque	Unequal expansion, shrinkage, gummed lubricants
	Voltage Life, Breakdown	Dielectric deterioration, excess wattage, exceeding temperature life of material
Low Temperature	Torque	Unequal expansion, viscosity increase of lubricants
	Noise	Viscosity increase of lubricants
	Resistance	Wire temperature coefficient, strain-gauge effect
Vibration & Shock	Noise	Contact bounce, dither
Humidity	Linearity, Resistance, Torque	Low and unequal insulation resistance, growth of hygroscopic materials
	Noise	Electrolytic corrosion
Altitude	Dielectric strength	Lower breakdown of air
	Power dissipation	Lower convection
Acceleration	Torque	Unbalanced rotor

Taken from Ref. 1

Carbon-film potentiometers exhibit certain peculiarities, in comparison with wire-wound types, that must be understood to apply them properly. By nature, they are intended for use principally as voltage dividers and not as rheostats. Specifications must be on a voltage output versus rotation basis and not on a resistance basis. Significant end resistance as well as resistance from tap-points to the film exist, but do not impair accuracy. In addition, their total resistance varies with temperature and to some extent with humidity, more than in wire-wound types. This latter characteristic is important when the potentiometer serves as an element in a resistive attenuation network. The problem is readily worked out when the potentiometer is adequately understood.

Table V summarizes some interesting aspects of carbon film potentiometer behavior. Table VI lists the performance characteristics of commercially available units.

Metal Film Precision Potentiometers– Although engineers have been working for some years on precision potentiometers with metal film as the resistance element, only recently have manufacturers promoted them commercially. Problems of achieving a stable metal film and low contact noise have been very difficult to solve, and room for improvement still exists. Nevertheless, manufacturers feel that here lies the ultimate answer to extremely high temperature requirements anticipated for the near future, and they are stressing current models where appropriate to broaden their

TABLE V

SUMMARY OF PRECISION CARBON FILM POTENTIOMETER CHARACTERISTICS

Linearities of ±.01 percent are obtained in a 5 inch diameter. Manufacturers claim these are the most accurate single turn linear precision potentiometers available on the market. Field experience indicates that accuracies of ±.02 percent are maintained over all conditions of environment called out by military specifications and over rotational life in excess of 10 million revolutions.

All performance is guaranteed over the temperature range of 55 to 150C for units of standard construction. Special purpose high temperature components have been manufactured capable of continuous operation at 500F with a required life of 5 million revolutions.

Nonlinearities can be developed with no loss of resolution, Nonlinear corrections for specific loads can be designed into the unit. Except for a modest tooling charge, CIC states that production costs for this feature are virtually unchanged.

Manufacturers claim a theoretical resolution of 5 micro inches. However, in practical production this performance is reduced by mechanical limitations such as bearing play and brush adjustment to the values in Table VI, still much finer than for comparable wire-wound potentiometers. The resolution is essentially independent of resistance value. This high resolution is excellent for sector pot applications.

Effective tap width is zero, as long as no current is drawn from the tap.

Failure is gradual, and can be detected at any point in its cycle.

Since the slider contact is a potential pick-off point having high resistance rather than a low resistance conventional contact, slider currents must be limited to a few ma. (This is also true of metal film potentiometers).

own experience and to aquaint the application engineer with the special virtues of this technique.

Many manufacturers offer metal-film potentiometers for trimming applications. Successful precision types are being widely sold principally by Technology Instrument Corp., Servomechanisms, Inc., and Fairchild Controls Corp. These companies currently offer a basic miniature model available in a variety of special types. Units offered are all single-turn.

Problems in metal-film potentiometers are stability of total resistance under environmental test, and resistance noise at the wiper, especially with rotational wear. Characteristics of metal-film potentiometers offered by these companies are summarized in Table VII. The table includes brief discussion of these characteristics.

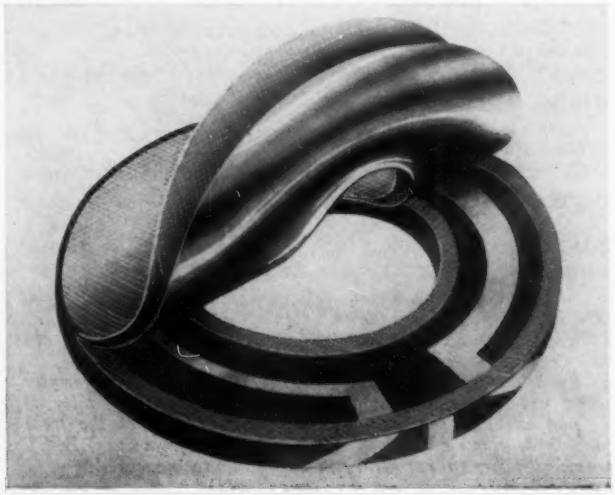

Fig 2—Hermetic resistance element of TIC metal film pot with diaphram cover and metal film peeled back.

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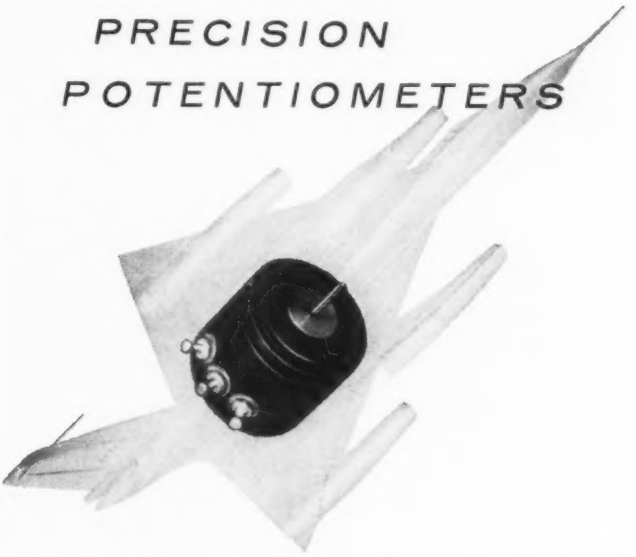

Waters LO-TORK Potentiometers with Bird Jewel Bearings are used on U.S. Air Force Supersonic bombers.

Here's how Bird Sapphire Jewel Bearings helped a prominent manufacturer of electrical instruments to make a major product advance.

Waters Manufacturing, Inc., manufacturers of precision potentiometers, were asked to design a miniature potentiometer with minimum torque and reliable operation when operated in a contaminated fuel mixture. The result was the new Waters LLT ⅜ LO-TORK potentiometer with jewel bearings — an entirely new concept in miniature potentiometers.

Bird Sapphire Jewel Bearings are specified in the new Waters LO-TORK Potentiometers because they provide higher accuracy and longer instrument life. Waters LO-TORK Potentiometers with Bird Sapphire Jewel Bearings stand up under even the most rugged accelerated corrosion tests conducted by the Armed Forces. In fact, Waters LLT ⅜ potentiometers are now being used in fuel flow meters where they must withstand the rigors of jet fuel.

Bird Precision Jewel Bearings have been used by the foremost manufacturers of electrical, aircraft and timing instruments and recorders. They are available in a wide range of standard types, sizes and complete assemblies — or custom-built to your specifications.

If your product design calls for jewel bearings, our engineering staff is at your service. A request on your letterhead for Bulletin 100-9 will receive our prompt attention.

Richard H. Bird & Co., Inc.

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PRECISION POTENTIOMETERS (Cont.)

T.I.C.'s Metal Film Potentiometer is distinguished by the hermetic seal of the resistance element, with all the attendent environmental advantages.

The pressure piece, acting through the diaphragm cover, causes a dimple in the gold foil which contacts the vacuum deposited metal film. Fig. 2 shows the hermetically sealed resistance element in detail with the diaphragm cover and gold foil peeled back to reveal the hermetically sealed construction.

Users are cautioned that the novelty of metal film pots and major design differences in their available types make close coordination with the manufacturer necessary in making a selection.

Conducting plastics, a class of materials having useful resistance characteristics, are also used in infinite resolution potentiometers. Markite Corporation of New York has developed a variety of both linear motion and rotary types, incorporating the important characteristics of film type units. The conductive plastic track provides inherent toughness, extreme wear and corrosion resistance. Like other film units, the resistive element is not subject to failure by sudden open circuiting. Standard accuracies of miniature single-turn units are of the order of 1 per cent, with closer tolerances available on special order.

TABLE VI

PERFORMANCE CHARACTERISTICS OF CARBON FILM PRECISION POTENTIOMETERS

Computor Instruments Corp.

TYPE	LINEAR AND NON-LINEAR						SINE-COSINE (1)			
Model	78	103	105	205	305	505	106	206	306	506
Diameter, inches	7/8	1 3/32	1 3/32	2	3	5	1 3/32	2	3	5
Case Length	.575	.156	.635	.960	1.100	1.675	.635	.960	1.100	1.675
Additional Length per Gang	.240		.240	.465	.690	1.265	.635	.960	1.100	1.675
Shaft Diameter	.1250		.1250	.2500	.2500	.2500	.1250	.2500	.2500	.2500
Mechanical Rotation	360° CONTINUOUS									
Electrical Function Angle	320°	350°	350°	350°	350°	350°	360°	360°	360°	360°
Resistance Range	1K to 250K ± 10%						20K Quad. Max.	30K Quad. Max.	50K Quad. Max.	
Best Linearity or Conformity	.3%	.2%	.2%	.05%	.025%	.01%	.3PP	.15PP	.15PP	.025%PP
Virtual Resolution (2)	1/40,000	1/75,000	1/75,000	1/200,000	1/300,000	1/500,000	1/75,000	1/200,000	1/300,000	1/500,000
Wattage (3)	2	2	2	4	4	6	2	4	4	6
Temperature Range (4)	−55°C to 85°C									
Taps, Maximum No. (5)	4	7	7	12	18	30				
Starting Torque in.—oz.	.06	.015	.08	.10	.15	.25	.1	.2	.25	.35
Guaranteed Life	IN EXCESS OF 2 MILLION CYCLES AT 100 RPM.									

FOOTNOTES

(1) Sine-Cosine types available with 2 wipers (Sine, Cosine, minus Sine, minus Cosine) and with ground taps (at 0 and 180 degrees).
(2) This resolution caused mainly by wiper spring and other mechanical effects.
(3) For single cup at 25C.
(4) All units are available for operation to 150C on special order.
(5) Available both with infinite and zero series resistance types.

ELEKTRO-SERV CO.

The unit described by the following data is representative of standard units, and can usually be varied to suit most potentiometer applications. Diameter of the unit is 1 1/16 inch. The company also makes a 7/8 inch diameter unit.

RESISTANCE:
1) 10K-2 megohms ± 5% for linear functions.
2) Resistance of non-linear functions is dependent on the individual function.

FUNCTION TOLERANCE:
1) linear functions ..... ± 1%[1-3]
2) non-linear functions ..... ± 3%[1-3]

RESOLUTION ANGLE ..... 0 degree, .007 degree Minimum
ELECTRICAL FUNCTION ANGLE ..... 350 degree[2]
ELECTRICAL CONTACT ANGLE ..... 357 degrees[2]
MECHANICAL ROTATION ..... continuous
POWER DISSIPATION ..... 2 watts @ 40C

TAPS:
Maximum number per element 7
Accuracy of tap location ..... 1 degree
Tap width ..... 0 degree

NUMBER OF SECTIONS:
Model 20 limited by torque or run-out considerations.
Model 20B-3 without double shaft extension, 2 with maximum.

STARTING TORQUE:
Model 20 ..... .05 oz.-in.
Model 20B ..... .12 oz.-in.
For each additional element add ..... ±0.20 oz.-in.

TEMPERATURE COEFFICIENT —01%/degreeC over —55C to 100C ambient temperature range
GUARANTEED LIFE ..... 1 million cycles at 100 rpm

NOTES:
1 Listing standard other tolerances available. To 0.1% attainable on standard units.
2 On continuous elements, function and contact angles are 369 degrees.
3 Function tolerance is defined as independent conformity when used as a voltage divider. Independent conformity is defined as: The maximum deviation, in percent of the total measured electric output, at any point, from the BEST specified function curve drawn through the measured points. Units available rated at one watt 225C, 3 watts at room temperature. No degradation of performance.

New 3-Way Nylon-Body Solenoid Valve...

List Priced as Low as $10.75...

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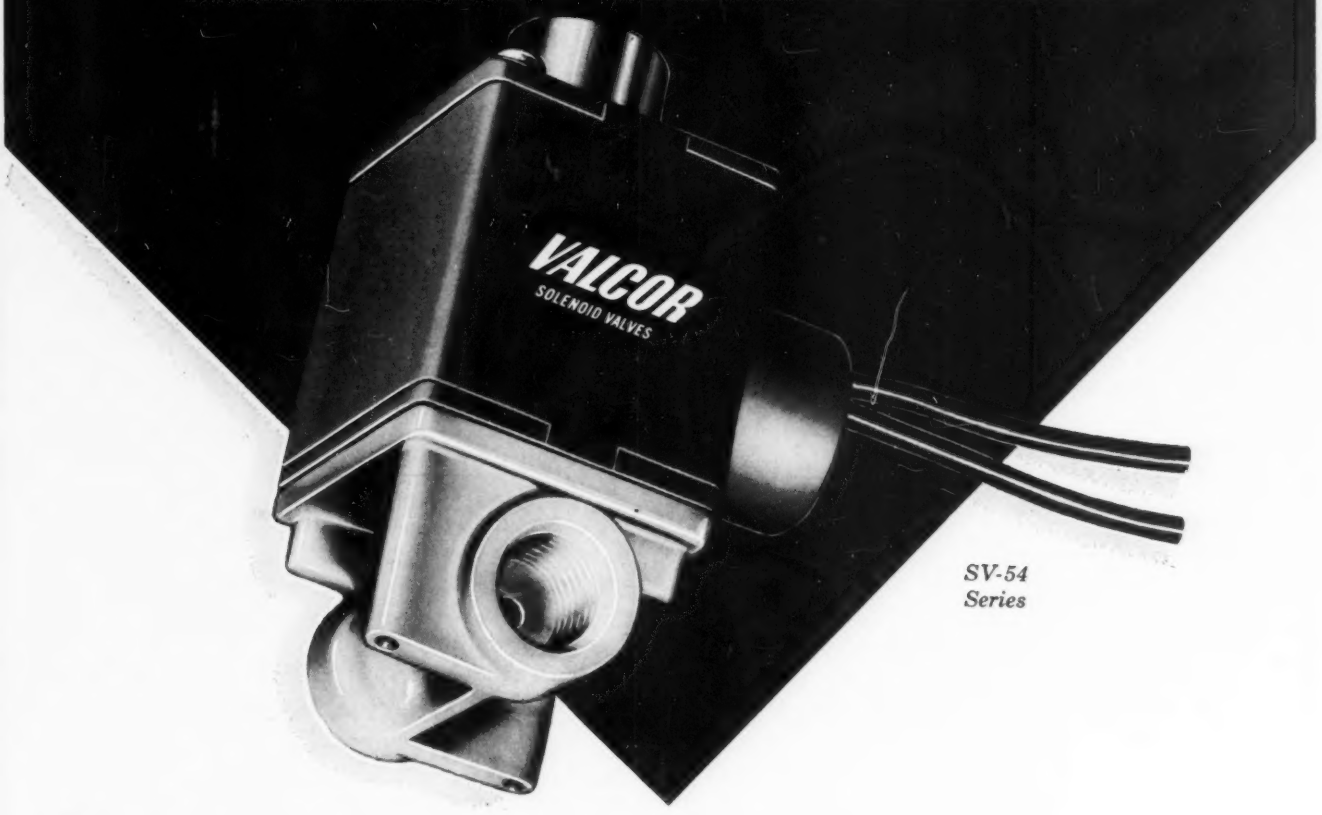
Outlasts, Outperforms Steel!



SV-54 Series

VALCOR'S new 3-way Nylon solenoid valve, SV-54 Series, outlasts and outperforms steel, yet is list priced as low as $10.75! In general purpose and O.E.M. installations, where millions of operating cycles are essential, this new Valcor valve not only works best but costs less.

Its nylon seat outlasts steel...its port threads outlast steel... pound for pound it's *3 times stronger than steel.* Dry seal threads, no compound is needed—and they won't loosen even under severe vibration. Nylon is non-corrosive so you have no atmospheric problems. And the stainless plunger is a reliable workhorse for millions of cycles. Bubble tight sealing. Available in normally open, normally closed and "directional control" configurations in all normal AC and DC voltages...1½" square x 3" long (valve illustrated).

Write today for complete technical data on this shock-resistant, pressure-proof valve—the 3-way nylon-body valve, SV-54 Series, that's 3 times stronger than steel, yet costs less. Try it on your toughest application.

VALCOR SOLENOID VALVES

VALCOR ENGINEERING CORP.

5374 Carnegie Avenue, Kenilworth, New Jersey

CIRCLE 28 ON INQUIRY CARD

TABLE VII

PERFORMANCE CHARACTERISTICS OF METAL FILM PRECISION POTENTIOMETERS

SERVOMECHANISMS, INC. Single Turn Film Pot

CHARACTERISTICS

Diameter: 1-1/16 in.

Independent Linearity: ±1 percent, ±0.5 percent in values less than 2k. Substantially no change of linearity with mechanical life.

High Temperature Test: Load life tests have been conducted at 100C with 2 watts dissipation for 1000 hours with resistance change less than 3 percent. Load life tests have been satisfactorily conducted for 1000 hours at 200C, but insufficient data is available to give specific guarantees.

Resistance Stability: Less at higher ohmic values.

Resolution: Angular resolution is less than 0.01 degree, but tests have not yet measured the true values.

Construction: Resistance element, taps, terminals, all applied by vacuum deposition to give rugged unitized construction.

End and Tap Resistances: Order of few ohms. When tap or end resistances of less than 20 to 50 ohms are required, a flat spot of a degree or so may occur in the output characteristic.

Electrical Angle: 350 degrees maximum in present models. Can be readily made for continuous electrical rotation with multiple taps.

Resistance Range: 50-10k ohms. High resolution is present regardless of resistance.

Torque: 0.01 oz-in is normal without sacrifice of life or noise.

Vibration: 2000 cps at 10 g is standard without resonance;
2000 cps at 200 g without damage.

Environmental: Manufacturer states "a modification from standard construction makes our pot capable of withstanding humidity, salt spray and fungus tests. In such pots the shaft torque is under 1 oz-in." Environmental requirements usually taken from MIL-E-5272 and MIL-Std-202.

Resistance Tolerance: ±5 percent, ±10 percent above 10k.

Power Rating: 2 watts.

Future Goals: Ultra-high temperature, 500C and above. Also, wiper that does not physically contact the resistance element, but uses a sealed film resistance element to give greatly improved life.

FAIRCHILD CONTROLS CORP. 3/4" Diameter Filmpot, type 771

ELECTRICAL CHARACTERISTICS

Resistance Range, ohms: 100 to 20K ± 10%, 20K to 50K ± 15%

Resolution: Infinite

Linearity-independent (dependent upon resistance value closer tolerances can be supplied): ± 1.5% up to 20K ± 2.0% up to 50K

Electrical Function Angle: Max 345 degrees

Wattage: 3 watts at 85C

Terminal Voltage: 500V ac max

Dielectric Strength—Terminal to Ground:

At sea level 1000V rms 60 cps

at 60,000 ft 550V rms 60 cps

Operating Ambient Temperature Range: —55C to +225C

Noise Characteristics: 400MV max

Number of Taps per cup: 2 max

Accuracy of Taps: ±2 degrees[a]

Tap Width: 1.5 degree max[b]

Service Life: up to 500,000 cycles dependent on resistance value & operating conditions

Temperature Coefficient of Resistance: depends on resistance value, for example: +400 ppm at 100Ω to +100 ppm at 100Ω

MECHANICAL CHARACTERISTICS

Resistance Element precious metal on inorganic substrate

Mechanical Rotation Continuous

Torque 0.1 to 0.5 oz-in or greater as required

Weight 0.9 oz max

NOTES:
(a) Closer tolerances can be supplied. Standard—340 degrees ±2 degrees.
(b) May be reduced under special conditions.
The manufacturer points out that due to the variety of customers' requirements, these specifications are offered as a standard and as a guide to design engineers. Variations on most of these specifications can be obtained to meet particular applications.

TECHNOLOGY INSTRUMENT CORPORATION. Single Turn Film Pot

ELECTRICAL CHARACTERISTICS

Standard Resistance Range:

MFR-1—1k, 25k ohms (1-1/16 in diameter)

MFR-2—1k, 50k ohms (2 in diameter)

Equivalent Noise Resistance: Less than 100 ohms.

Linearity: Less than 0.5 percent, independent.

Resolution: Essentially infinite.

Dielectric Strength: Will withstand a 60 cps, 900 volt rms signal for 1 minute duration at atmospheric pressure; a 60 cps, 450 volt rms signal for 1 minute at 3.4 inches of mercury pressure.

Electrical Angle: 350 degrees, ±3 degrees maximum.

Temperature Coefficient of Resistance Element: Less than 0.0003 ohms/ohm/degreeC.

Insulation Resistance: Greater than 10 megohms.

MECHANICAL CHARACTERISTICS

Torque: Less than 1 oz-in (std.); *less than 0.5 oz-in special.*

Rotation: Continuous or as desired.

Mounting: Servo mount standard; other mounting special.

Mounting Hardware: Non-corrosive type used exclusively, per U.S. Army 72-53.

Shaft: Centerless-ground stainless steel type.

Shaft Play: Not more than 0.001 in.

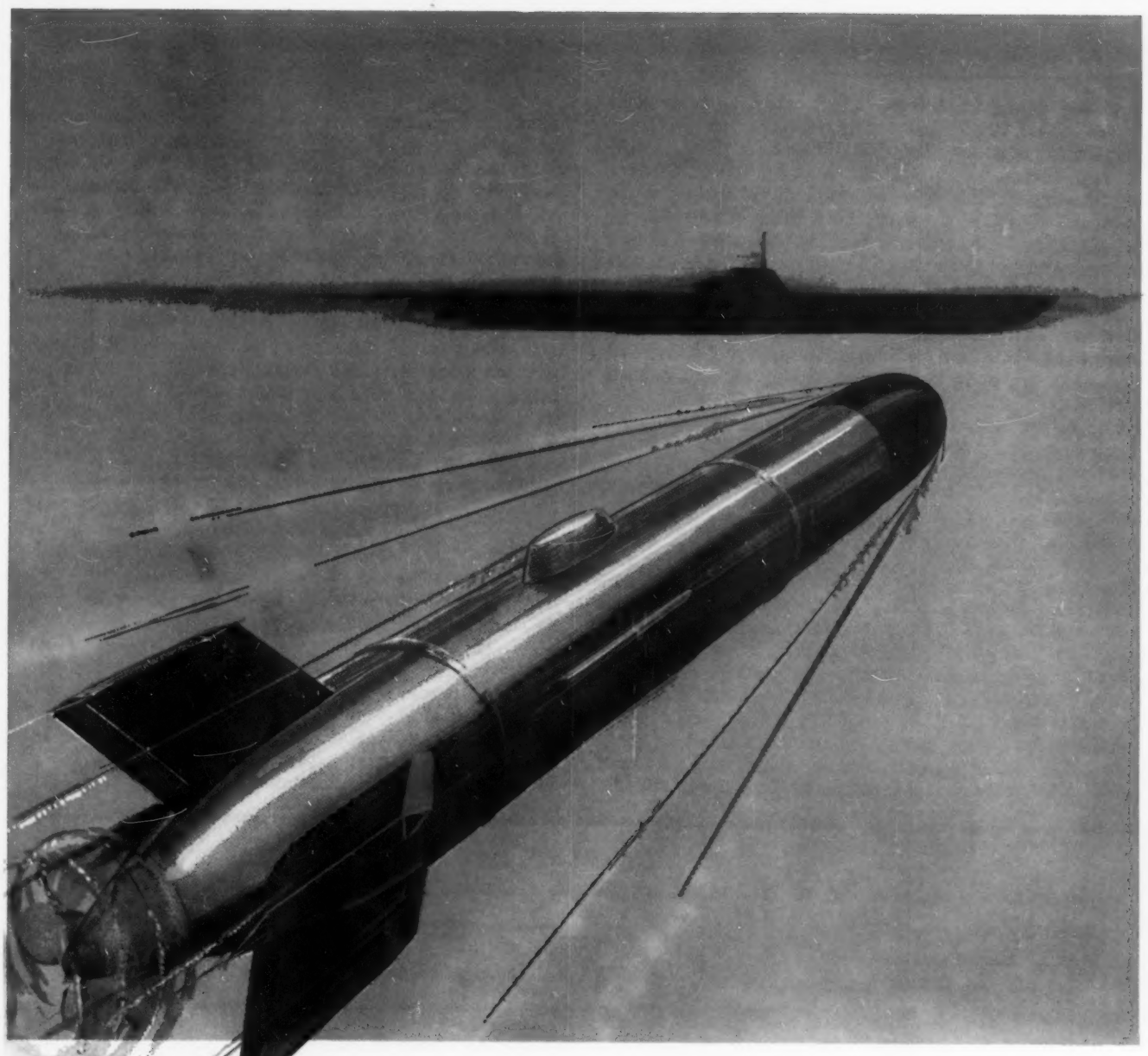
Concentricity: Within 0.001 in.

Perpendicularity: Within 0.001 in.

Rotating Contact: Rotating contact electrically insulated from shaft.

Resistance Element: Metallic film protected against mechanical damage and is substantially dust and moisture proof.

Construction of these units is unique providing full hermetic sealing while maintaining moderately low torque and zero backlash. Seal provides a dust and humidity-free enclosure.



SILVERCEL® BATTERY POWERED RAT STALKS SUBS – WITH DEADLY ACCURACY!

Through every stage of its submarine-stalking mission, the Navy's revolutionary RAT (rocket-assisted torpedo) depends on YARDNEY SILVERCEL® BATTERIES to power remarkable propulsion and homing devices.

From the largest and most complex missile to the smallest subminiature device, today's advanced technology requires maximum energy from a package of minimum size and weight. As in the RAT, YARDNEY SILVERCEL® BATTERIES provide reliable energy with only 1/5 the size and 1/6 the weight of ordinary batteries. They are used in 19 U. S. missiles . . . including major intercontinental and intermediate-range missiles.

Write today for complete technical data and literature to find out how you can gain needed power, save vital space and weight.

YARDNEY ELECTRIC CORP.

*"Pioneers in Compact Power"**

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MANUFACTURERS OF YARDNEY SILVERCEL®, YARDNEY SILCAD® AND YARDNEY ARCTIC® BATTERIES

TRIMMING POTENTIOMETERS

Trimming potentiometers are widely used in many fields of instrumentation where precise settings or occasional readjustments are required. Usually used as voltage dividers but frequently as variable resistors, their principal requirements are compactness, stability of setting under shock and vibration, reliability to very high temperatures, and good resolution and low backlash for ease of setting. A large electrical angle simplifies adjustment. Factors such as linearity are not generally important. Categories of trimming potentiometers include single-turn rotary vs multi-turn screw actuated types, carbon or metal film vs wire-wound types, and an impressive variety of convenient mechanical types for compact packaging of one or more units.

Technology Instrument Corp. was one of the first companies to recognize the trimming potentiometer as a distinct item with its own special requirements and area of application. Today T.I.C. manufactures a complete line of both wire-wound and metal film types meeting severe military specifications (Table VIII).

In the special but highly important category of lead screw-actuated potentiometers, Bourns Laboratories, Inc. has a complete line including wirewound and carbon film units available in both military and commercial grades, as well as a variety of compact packages. Bourns claims exceptionally good stability and low cost in their new carbon film types (Table IX). Note that carbon film units are not recommended as variable resistors. Many other manufacturers in the buyers' guide make trimming pots.

Since electrical requirements of these pots are not stringent, selection should be made on the basis of suitable mechanical configurations, resistance to anticipated environmental extremes, reliability of the sources and price.

Bourns is starting production on a Trimpot with a maximum operative temperature of 225C. Standard load life at rated power for Bourns pots is 1,000 hours per MIL-R-19A. Test data suggests a 2,000 hour life at slightly lower ratings. At negligible dissipation, customer information indicates from 5,000 to 10,000 hours reliable life. Independent linearity of these units is held by internal specification requirements to 5 percent maximum. However, actual linearity averages 1 percent or less in resistance of about 1,000 ohms and above. After 200 cycles (one cycle being equivalent to a complete two way traverse of the resistance element) total resistance shift of Bourns units is less than 2 percent. After 500 cycles good continuity and absence of mechanical failure are required.

Carbon type trimming potentiometers, according to Bourns, are characterized by a higher temperature coefficient, lower power rating and increased contact resistance over those of wire-wound potentiometers. Usually carbon types are not suited to humid environments because of their sensitivity to moisture. Bourns has developed a new resistor element deposited on a ceramic base which passes MIL-STD 202, Method 106 humidty without sealing; average change in total resistance is less than 5 percent.

Bourns predicts a 600C maximum operating temperature as the most significant future gain in environmental performance. As yet no military specification has been written on lead screw actuated potentiometers, but the Navy (BuShips) is working on one.

TABLE VIII

PERFORMANCE CHARACTERISTICS OF TECHNOLOGY INSTRUMENTS CORPORATION'S FILM TYPE TRIMMING POTENTIOMETERS

ELECTRICAL CHARACTERISTICS

Standard Resistance Ranges:

RTW — 50, 100, 500, 1K, 5K, 10K, 25K, 50K, 100K

RTF — 50, 100, 500, 1K, 5K, 10K, 25K

Accuracy Of Total Resistance @ 25C: ±10%

Independent Linearity: ±5%

Usable Resistance Range: 100%

Rated Temperature Coefficient: RTW — .00004 parts/C max.
RTF — .00025 parts/C max.

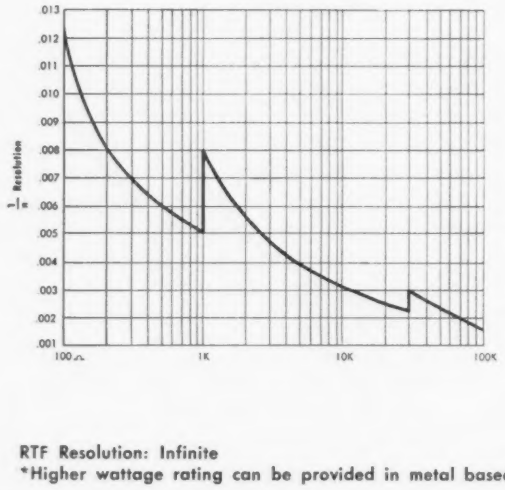
Ambient Lemperature Range: From —55C to +225C standard.

Dielectric Strength: 500 d-c between leads, shaft & mounting.

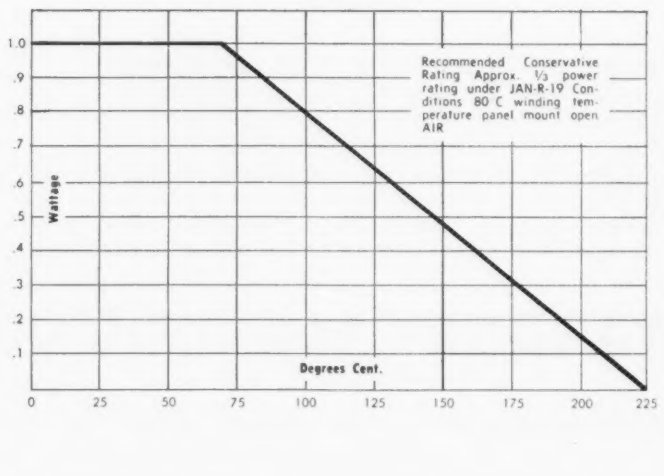
MECHANICAL CHARACTERISTICS

Terminals: RTW-L1 Tinned Lugs; RTW-W1 Teflon Insulated Leads; RTW-P1 Tinned Printed Circuit Leads

RTW Resolution



*RTW Power Rating**



RTF Resolution: Infinite

*Higher wattage rating can be provided in metal based unit.

TABLE VIII (Cont.)

Mechanical Characteristics (cont.)
Housing: High temperature plastic

Shaft: Stainless steel lead screw with screw driver slot for adjust.

Maximum End Stop Torque: 2 oz. in—Rotation beyond stop protected by unique safety overide device.

Mechanical Rotation: 25 turns ±2 turns

Weight: 0.12 oz.

ENVIRONMENTAL CHARACTERISTICS

Element: Wire wound.

Storage Temperature Range: Down to —62C

Vibration: Per mil—std—202A, method 204, condition B

Vibration Endurance: Per mil—std—2-2, method 201, condition A

Shock: Per mil—std—202, method (100 G's shock in each of three mutually perpendicular planes—15 shocks total)

Moisture Resistance: Per mil—std—202, method 106 with rated wattage applied.

Temperature Cycling: Per mil—std—202, method 102, condition A

Altitude Test: Per mil—std—202A, method 105A, condition D. (100,000 ft.—200 VDC dielectric strength)

Immersion Seal: Per mil—std—202, method 104, condition A

Sand & Dust: Per mil—E 5272A, procedure 1

Salt Spray: Per mil—std—202, method 101, condition A

Load Life: 1000 hrs, rated power 1½ hrs on, ½ hr off for 1000 hrs

Life: 1000 sweeps—change in total resistance not greater than 5%.

TABLE IX

PERFORMANCE CHARACTERISTICS OF BOURNS' TRIMMING POTENTIOMETERS, MILITARY GRADE 9

		CLASS NAME	MODEL	TERMINALS (1)	RESISTANCES (ohms) (2)	END SETTINGS (%)	POWER RATING (watts)	MAXIMUM OPERATING TEMPERATURE (° C)	HUMIDITY-PROOF (MIL. SPECS) (5)	SIZE (inches) H.	W.	L.	STANDARD RESISTANCES (ohms)
WIREWOUND	POTENTIOMETERS	TRIMPOT®	200	L,S,P	10Ω to 50K	0-0.7(3)	0.25	105	No	5/16	1/4	1 1/4	10 to 10K 20K 50K
		HI-R® TRIMPOT (4)	207	L	100Ω to 100K	0-7.5	2.0	175	No (4)	1 3/16	9/32	1 1/4	100 to 50K 100K
		TWINPOT®	209	L	Dual Element... Refer to Model 200				No (4)	5/16	1/2	1 1/4	10 to 10K 20K
		TRIMPOT JR.* (7) (sealed)	220	W,L	100Ω to 20K	0-0.1(3)	1.0	175	Yes	.315	.17	1	100 to 10K 20K
		TRIMPOT, (sealed)	236	L,S,P	10Ω to 50K	0-0.1(3)	0.8	135	Yes	23/64	19/64	1 23/64	10 to 10K 20K 50K
		TRIMPOT, High-Temp. (8)	260	L,S,P	10Ω to 50K	0-0.1(3)	1.0	175	No	5/16	1/4	1 1/4	10 to 10K 20K 50K
	VARIABLE RESISTORS	TrimR®	201	L	20K to 100K	0-0.7(3)	0.25	105	No	5/16	1/4	1 1/4	20K & 25K 50K 100K
		Hi-R TrimR (4)	208	L	100K to 200K	0-7.5	2.0	175	No (4)	1 3/16	9/32	1 1/4	100K & 150K 200K
		TrimR® (sealed)	231	L	20K to 100K	0-0.1(3)	0.8	135	Yes	23/64	19/64	1 23/64	20K & 25K 50K 100K
		TrimR High-Temp.	261	L	20K to 100K	0-0.1(3)	1.0	175	No	5/16	1/4	1 1/4	20K & 25K 50K 100K
CARBON	POTENTIOMETERS	Carbon TRIMPOT General Purpose	120-15	L	20K to 1 meg	0-7.5	0.2	95	No	5/16	1/4	1 1/4	20K to 1 meg
			212	S	20K to 1 meg	0-7.5	0.2	95	No	5/16	1/4	1 1/4	20K to 1 meg
			213	P	20K to 1 meg	0-7.5	0.2	95	No	5/16	1/4	1 1/4	20K to 1 meg
		TRIMPOT RESISTON 1 Carbon	215	L,S,P	20K to 1 meg	0-1.0	0.25	125	Yes	5/16	1/4	1 1/4	20K to 1 meg

FOOTNOTES:

1. *S=Solder lugs* *P=Printed circuit pins*
   L=Stranded insulated leads *W=Solid wire*
2. *Standard resistance (ohms)*

10	*200*	*5K*	*100K*
20	*500*	*10K*	*200K*
50	*1K*	*20K*	*500K*
100	*2K*	*50K*	*1 meg*

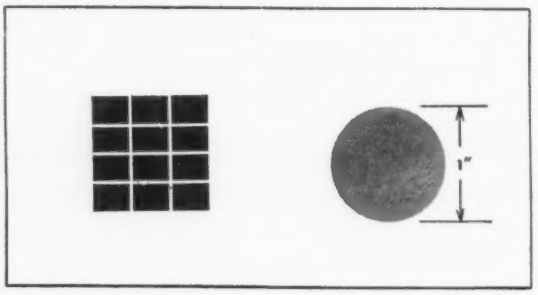
Units are available in these resistances within resistance limits shown in chart. Other resistances on special order.

3. *Or 0 to 0.5 ohms, whichever is greater.*
4. *Consult manufacturer for humidity-proof model.*
5. *All military models listed are sealed against sand and dust and are splash-proof.*
7. *Trademark.*
8. *Bourns reports that a 225C Trimpot is available at this time and will very shortly be in full production status.*
9. *Commercial grade meets less stringent enviromental characteristics but offers similar performance at lower cost.*

HOW ONE CONCEPT IN POTENTIOMETER DESIGN SOLVES THREE BASIC PROBLEMS

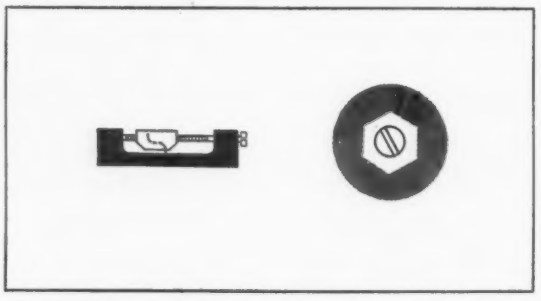
SPACE-SAVING SIZE AND SHAPE

You can pack a lot of Bourns potentiometers into a small space—12 in one square inch of panel area (or 17 TRIMPOT JR.* units!) Fit them into corners, between other components, flat against chassis or printed circuit boards. Mount them individually or in stacked assemblies.



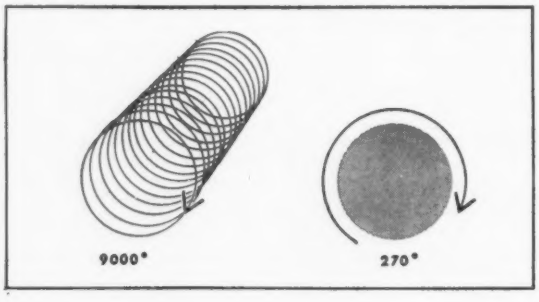
ADJUSTMENT STABILITY

Bourns potentiometers are *self-locking* (no lock nuts required). Any adjustment *remains* stable. Shock, vibration or acceleration can't affect a setting. Bourns potentiometers are helping thousands of engineers make reliability a reality.



CIRCUIT BALANCING ACCURACY

Bourns potentiometers are 33 times as accurate as conventional single-turn rotary types—the screw-actuated mechanism provides 9000° of rotation instead of only 270°. Circuit balancing, calibration—adjustments of all types are easier, faster, more precise. And repeatability is assured.



BOURNS
Laboratories, Inc.

P. O. Box 2112 • Riverside, California

ORIGINATORS OF TRIMPOT® AND TRIMIT®
PIONEERS IN POTENTIOMETER TRANSDUCERS FOR POSITION, PRESSURE AND ACCELERATION

*Trademark

CIRCLE 30 ON INQUIRY CARD

HERE ARE ADJUSTMENT POTENTIOMETERS TO MEET ALL YOUR REQUIREMENTS

high performance military potentiometers and rheostats

General Purpose Type

The original wirewound TRIMPOT®. Model 200 (terminals L, S or P—see drawings below). 105° C operation. 0.25 watt. Also available as a rheostat, Model 201 TrimR® (terminal L only).

High-Resistance Wirewound

Hi-R® TRIMPOT Model 207 (L). Resistances to 250 K. 175° C operation. Two watts. Rheostat: Hi-R TrimR Model 208. (L).

Micro-Miniature Potentiometer

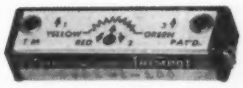
The TRIMPOT JR.* Model 222 is so small you can fit 17 units in one square inch of panel space. 175° C operation. One watt. Humidity proof. (Terminals L or W).

High-Resistance Deposited Carbon

An unusually significant achievement in military quality potentiometers—infinite resolution at 125° C operation. 0.25 watt. Uses the RESISTON* element, a product of 3 years of Bourns research. 20K to 1 megohm range. TRIMPOT Model 215. (L, S or P).

Dual Potentiometer

TWINPOT® Model 209 is two potentiometers in one. (L). 105° C operation. 0.25 watt.



High-Temperature Operation

175° C operation. One watt. TRIMPOT Model 260. (L, S or P). Available as a rheostat Model 261 (L).

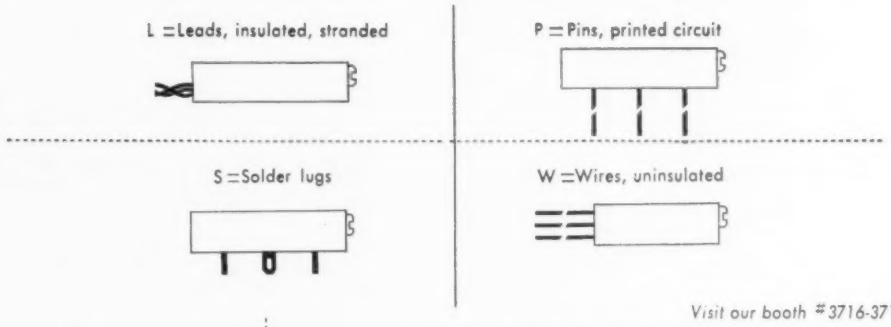
Humidity Proof, 135°C Operation

TRIMPOT Model 236. (L, S or P). 0.8 watt. Also available as a rheostat, Model 231. (L).

low-cost commercial adjustment potentiometer

TRIMIT® — an important new development for manufacturers of computers, industrial controls, communications equipment and high-quality test and measuring equipment. Provides 33 times the adjustment accuracy of single-turn rotaries, occupies only a fraction of the space, and has far greater stability of setting—*at no additional* cost. Wirewound Models 271 (L), 273 (S), 275 (P). Carbon Models 272 (L), 274 (S), 276 (P).

military and commercial units available in these terminal types:



Visit our booth #3716-3718 at the I. R. E. Show

Write for detailed technical information on Bourns Potentiometers. Please specify the model or type and mention your application.

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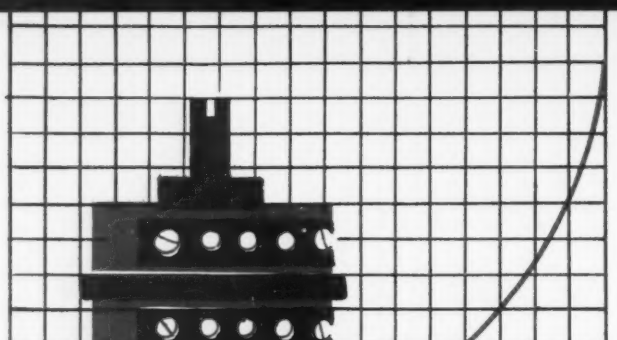
CIRCLE 30 ON INQUIRY CARD



Potentiometer Standards

Present status of potentiometer standards is well summarized by Helipot in the following quotation from Ref. 1. "Until recently, the only detailed specification available has been JAN-R-19. This covers low-operating-temperature variable resistors of the wire-wound semi-precision type. Although not directly applicable, it was used for many years as a guide to environmental testing of precision potentiometers, along with MIL-E-5272A, AN-E-19 (which later became MIL-E-5400) and various other general equipment and test specifications.

"In 1953, the Signal Corps published MIL-R-12934 (Sig C), a detailed specification applying directly to precision potentiometers. This was a step toward standardization, but did not cover all the environments of interest to the designer of airborne electronic equipment. This need lead directly to our next group of specifications.

"Interested organizations in industry have either published, or are in the process of publishing, precision potentiometer specifications. Among these is NAS-710, published in 1955 by the Aircraft Industries Association. This is a detailed specification using the environments of MIL-E-5272A as a general guide. A group of precision potentiometer manufacturers, under the auspices of RETMA, is preparing a detailed specification to be published in the near future. This is to be geared to the present state of the art and is aimed at standardizing a predominantly non-standard industry."

To establish at least some level of uniformity, manufacturers adhere where possible to the general provisions of NAS-710. Definitions of that specification as well as certain procedures are widely accepted. The following material extracted from NAS-710 is intended to assist the application engineer in devising the specification suited to his needs. Slight modifications in the texts have been made to make the material self-contained.

PRECISION POT DEFINITIONS (from NAS-710)

Resolution—A measure of the precision to which the input or output of a PVR may be set. To completely restrict resolution both electrical and angular resolution must be specified.

Electrical Resolution—A measure of the accuracy to which a PVR may be set with reference to the input. (The wiper arm is moved through the smallest finite angular displacement which will produce a single change in resistance or voltage.) The maximum incremental change in resistance or voltage output thus produced, observed anywhere in the total mechanical rotation of the PVR shaft, or specified portion thereof, when multiplied by 100 and divided by the total variable resistance or voltage, or specified portion thereof, is the percentage resolution of the PVR.

Angular Resolution—A measure of the precision to which the input of the PVR may be set with reference to the output. (The PVR wiper is moved thru the largest angular displacement which will produce no change in resistance or voltage.) The maximum incremental change in shaft rotation thus produced, observed anywhere in the total mechanical rotation of the PVR shaft, or specified portion thereof, is measured in degrees.

Direction of Rotation—Direction of shaft rotation is defined as clockwise (CW) or counterclockwise (CCW) when viewing the major mounting end of the PVR.

Noise—Noise is defined quantitatively in terms of an equivalent parasitic, transient, contact resistance in ohms, appearing between the wiper and the resistance element when the shaft is rotated. The equivalent noise resistance is defined independently of the total resistance, the resolution, the functional characteristics, and the total angle. The magnitude of the equivalent noise resistance is taken as the peak to peak value obtained. The wiper arm of the PVR is required to be excited by a specified current and rotated at a specified speed.

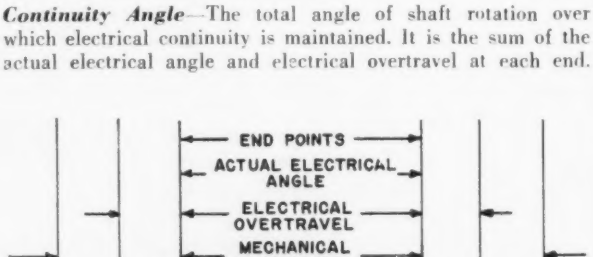
Mechanical Angle—The total angle through which the shaft can be rotated. When no stops are specified the mechanical angle is understood to be "unlimited".

Mechanical Overtravel—The angle of the shaft rotation between an end point and the near mechanical stop. This angle must be specified at each end. When no stops are specified, this angle is 360° minus the actual electrical angle.

Actual Electrical Angle—The actual angle between the end points.

Theoretical Electrical Angle—The angle that is specified on the specification control drawing and is effective in producing useful electrical output.

Continuity Angle—The total angle of shaft rotation over which electrical continuity is maintained. It is the sum of the actual electrical angle and electrical overtravel at each end.



PRECISION POT DEFINITIONS (cont.)

End Point—Point of sudden change in rate of change of resistance as the wiper moves from the overtravel region toward the variable resistance element. When the mechanical angle is less than the angle encompassed by the winding, the end points are at the mechanical stop positions.

End Resistance From End-Point—The resistance between the wiper terminal and an end terminal when the wiper is positioned at the corresponding end point.

Electrical Overtravel—The angle of shaft rotation over which there is continuity between the contact and the resistance element beyond each end of the actual electrical angle (Fig. 2).

Backlash—Backlash is the maximum difference in the angular position of the shaft in degrees which is obtained when the shaft is rotated to any prescribed electrical output from opposite directions.

Cup—a single PVR.

Gang—An assembly of two or more cups on a common shaft.

Phasing—The alignment of the respective tolerence bands of the individual cups of a gang with the tolerance band of the cup at the driven end. This automatically prescribes that voltage ratios of all cups of a gang fall within their respective tolerance bands at any angle of shaft rotation, when referred to the index point on the cup nearest the driven end.

Built-in Resistor—A specified resistor, internal or external, connected to the variable resistance element and forming an integral part of the cup assembly to provide a desired characteristic.

Test Point—A test point is an additional terminal used to obtain electrical access to the variable resistance element. It may be used to facilitate measurement on the resistance elements in cases where built-in resistors are employed.

Total Variable Resistance—Total variable resistance is the resistance between the end points.

Total Resistance—The resistance across the input terminals with the wiper arm so positioned as to give maximum resistance value.

Deviation—The difference between the actual electrical output and that specified by the function at any shaft angle. Deviation=Actual electrical output minus the specified electrical output.

End Error—The actual deviation that occurs at either angular extreme of the idealized characteristic from which the deviations are measured.

Lateral Run-Out—The total maximum difference between the high and low readings of a dial indicator suitably arranged to denote the out of squareness relation of the mounting surface with respect to the rotational axis of the shaft.

Run-Out of Shaft—Run-out of shaft is the maximum difference between the high and low readings of a dial indicator suitably arranged to measure the eccentricity of the shaft at any point on its exposed length when rotated in its own bearings with the body held stationary.

Run-Out of Mounting Surface Pilot—Run-out of mounting surface pilot is the maximum difference between the high and low readings of a dial indicator suitably arranged to measure the eccentricity of the pilot diameter. The shaft shall be clamped and the PVR body shall be rotated about its shaft when taking this measurement.

Radial Play—Radial play is the maximum difference between the high and low readings of a dial indicator suitably arranged to measure the total radial travel (sum of both directions) of the shaft in its own bearings. It is measured as closely as possible to the bearing in the front plate of the unit with a ½ pound radial load on the shaft at a distance ½ inch from the mounting surface.

End Play—End play is the maximum difference between the high and low readings of a dial indicator suitably arranged to measure the total axial travel of the shaft in its own bearings with a ½ pound axial load on the shaft applied alternately in each direction.

Tap—Electrical connections made to the variable resistance element at any point between the end points. Tap location is defined as being at the mechanical center of the effective tap width.

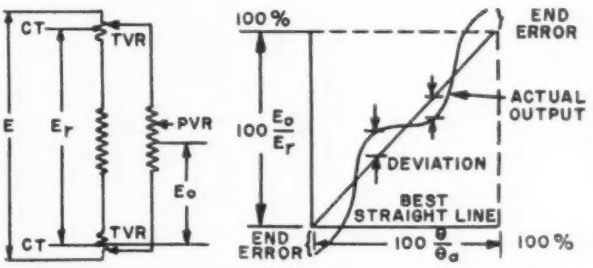
Effective Tap Width—That angle of mechanical rotation during which there is no change in voltage or resistance as the wiper is moved past the tap in any one direction.

List of Symbols

E = Total applied voltage
E_r = Input reference voltage
E_o = Output voltage
CT = Center tap
TVR = Trimmer variable resistor
PVR = Precision variable resistor
θ_a = Actual electrical angle
θ_t = Theoretical electrical angle
R = Total specified resistance
R_e = End resistor
R_c = Output resistor
θ = Any angle of shaft rotation from a reference

Independent Linearity—Definition: independent linearity is the maximum deviation (in percent of the input reference voltage, E_r) of the actual measured electrical output, E_o, at any point from the best straight line drawn through the actual outputs vs. rotation curve. (This line should be measured through the extent of the actual electrical angle.) The slope and position of the same straight line from which the linearity deviations are measured must be so adjusted as to minimize these deviations.

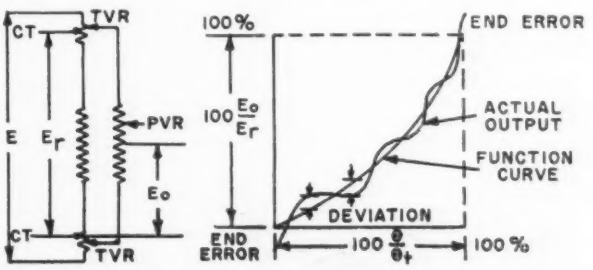
APPLICATION: Trimmer variable resistors are provided in the system and may be adjusted to average the PVR end errors to obtain a maximum of precision from the unit.



Terminal Linearity—Do not use. Specify straight line function to terminal conformity requirements.

Independent Conformity—Definition: Based on the specified angle (theoretical electrical angle) of electrical rotation, the independent conformity is the maximum deviation (in percent of the input reference volatge, E_r) of the actual measured electrical output, E_o, at any point from the best specified function curve drawn through the output vs rotation data. Independent conformity allows the average slope and the rotational axis intercept to be so adjusted as to minimize the conformity deviations.

APPLICATION: Trimmer variable resistors are provided in the system and must be adjusted to obtain the end errors specified for each unit by the manufacturer.



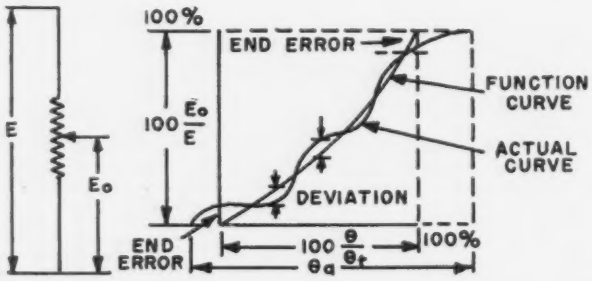
PRECISION POT DEFINITIONS (cont.)

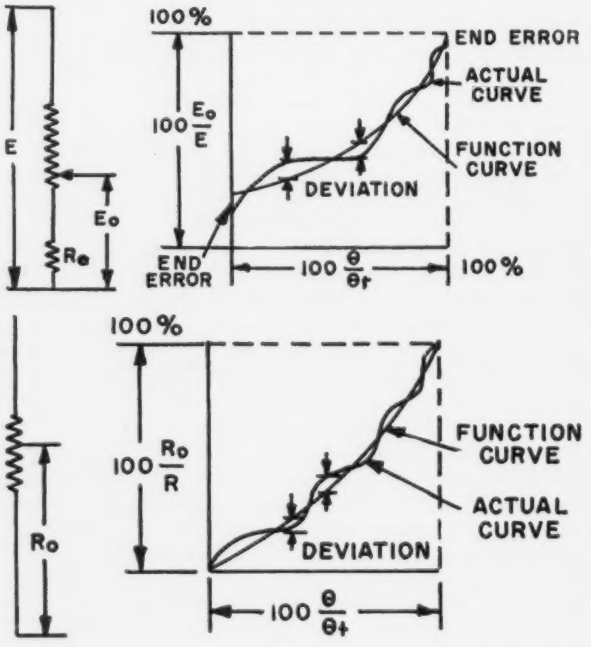
Terminal Conformity—Definition: Based on the specified angle (theoretical angle) of electrical rotation, the terminal conformity is the deviation (in percent of the total measured electrical input, E,) of the actual electrical output at any point from the specified functional curve drawn through the following theoretical points:

- Zero output at zero rotation.
- Maximum output at the specified function angle of rotation.
- Terminal conformity specifies the idealized characteristic curve to be drawn through points determined by the total output of the unit and the function angle. It does not require the error at these points to be zero.

APPLICATION:

- All units are completely interchangeable and no adjustments are made in the system to accommodate end errors at the ideal zero or 100 percent output points. This criterion may also be used to specify a linear function if so desired.
- An end resistor is required at either end to fill out the function.
- Rheostat connection (linear and non-linear). In this case the electrical output is in ohms and the deviation is a percent of the specified total resistance. There is no need for a tolerance on either the minimum total angle of rotation or the minimum total resistance as these are included in the conformity criterion.





Indexing—Definition: Indexing is the shaft alignment required between the PVR (in the case of a gang, the cup nearest the driven end) and an external angle divider. It provides the basis of all angular measurements.

APPLICATION:

- All functional units must utilize the indexing procedure.
- Functional zero is oriented by displacing a known angle of rotation from a known voltage point. This known voltage point and the known angular displacement shall be marked on the unit by the manufacturer.
- The index point shall be obtained with 100 percent voltage applied across the two input terminals.

GENERAL REQUIREMENTS–ELECTRICAL AND MECHANICAL (from NAS 710)

Noise—The equivalent noise resistance shall not exceed 0.1 percent of the total variable resistance or 100 ohms, whichever is the greater when tested as in the accompanying figure.

Temperature Coefficients—The temperature coefficient of the PVR including any built-in resistors shall not exceed ±0.01 percent per degree C. For more critical applications a value of 0.005 percent is recommended; for less critical applications a value of 0.1 percent is recommended.

Resistance Tolerance—The actual resistances of the total resistance and total variable resistance shall be within 5.0 percent of their specified values.

Useful Life—The useful life of a PVR shall be 500,000 cycles of the wiper arm (1,000,000 reversals) when tested with rated dissipation on a standard mount at approximately 40 rpm. Additional details of this test are described elsewhere in NAS 710.

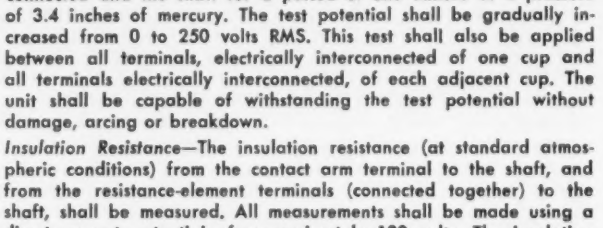
Impedance—The actual impedance of each resistance element in the PVR shall not differ from its actual DC resistance by more than 0.1 percent at 400 cycles per second.

Dielectric Strength—A sinewave test potential at 60 cps shall be applied between all terminals electrically interconnected and the shaft for a period of one minute (qualification tests) or 5 seconds (production tests) at standard atmospheric conditions. The test potential shall be gradually increased from 0 to 1000 volts RMS. This test shall be applied between all terminals, electrically interconnected of one cup and all terminals electrically interconnected, of each adjacent cup. The unit shall be capable of withstanding the test potential without damage, arcing, or breakdown.

Dielectric Strength at Reduced Pressure—A sine wave test potential at 60 cps shall be applied between all terminals electrically interconnected and the shaft for a period of one minute at a pressure of 3.4 inches of mercury. The test potential shall be gradually increased from 0 to 250 volts RMS. This test shall also be applied between all terminals, electrically interconnected of one cup and all terminals electrically interconnected, of each adjacent cup. The unit shall be capable of withstanding the test potential without damage, arcing or breakdown.

Insulation Resistance—The insulation resistance (at standard atmospheric conditions) from the contact arm terminal to the shaft, and from the resistance-element terminals (connected together) to the shaft, shall be measured. All measurements shall be made using a direct current potential of approximately 100 volts. The insulation resistance at 25°C and 50 percent maximum relative humidity shall be 100 megohms minimum.

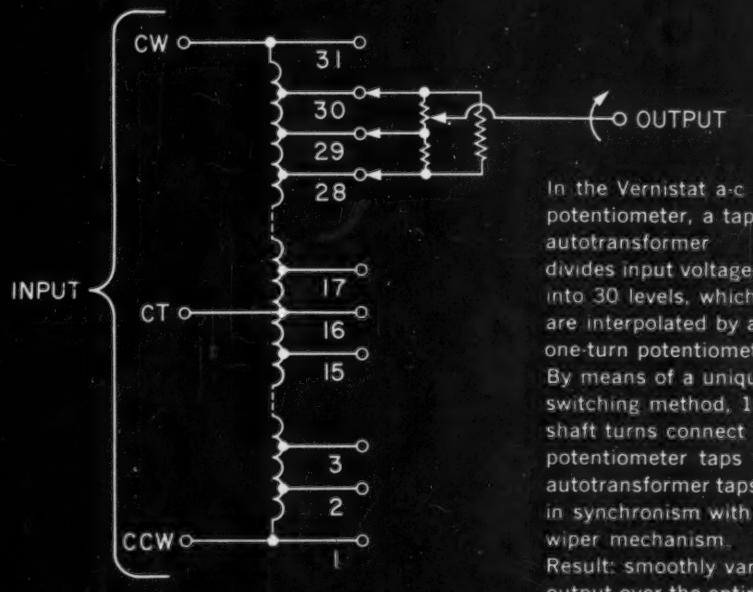
Radial Play—Radial play shall not exceed 0.001 inch.


PVR UNDER TEST
OSCILLOSCOPE
1 ma DC CONSTANT CURRENT SOURCE
MIN. INPUT IMPEDANCE 3 MEG. 400 CPS
VERTICAL INPUTS
BANDWIDTH 60 ∿ 50 KILOCYCLES

Noise Measuring Circuit. During this test, the PVR shaft shall be rotated in both directions at an angular rate not exceeding 4 rpm. The equivalent noise resistance shall not exceed the value as specified.

continued on next page

with this unique principle...



In the Vernistat a-c potentiometer, a tapped autotransformer divides input voltage into 30 levels, which are interpolated by a one-turn potentiometer. By means of a unique switching method, 10 shaft turns connect potentiometer taps and autotransformer taps in synchronism with the wiper mechanism. Result: smoothly varied output over the entire voltage range.

and these combined features...

Low output impedance *(as low as 45 ohms)* with high input impedance *(as high as 200,000 ohms)* • High resolution *(up to 0.004%)* • Low phase shift *(as low as 0.2 minutes)* • High linearity *(as low as 0.01%)*

WHAT SYSTEM DESIGN PROBLEMS CAN VERNISTAT* HELP YOU SOLVE?

With a fundamentally new concept in relating shaft rotation to voltage, the Vernistat a-c potentiometer brings to electronic designers a wholly new combination of features not previously available in a standard potentiometer. As a result, new design improvements and economies are made possible in servo systems, analog computers, many other similar applications—perhaps including yours, too – with these advantages:

Reduces system complexity and cost. With this one compact device, you can eliminate isolation amplifiers, shielded cables, summing resistors with resultant signal loss, and separate transformers with accurate center taps. Quadrature rejectors, as well as other phase-compensation schemes, are generally unnecessary.

Increases system reliability and accuracy. With fewer system elements, system reliability goes up. High linearity, an inherent Vernistat feature, is maintained over its entire life. Low phase shift, another plus, helps attain accuracy.

Permits greater design freedom. The Vernistat is easily modified to provide similar basic features in nonlinear functions with excellent conformity. Unlike helical-type units, it can be continuously rotated because of its planetary principle. A wide selection of models is available which meet military specifications.

• • •

Besides precision a-c potentiometers, Vernistat products include function generators (adjustable nonlinear potentiometers) and variable ratio transformers. Design principles, applications, technical data, prices, and specifications are all included in information available. Write today for full details.

*vernistat®— *a new design concept that unites in one compact device the best of both the precision autotransformer and the multiturn potentiometer.*

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vernistat division

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Test	Procedure I (Min. Severity)	Procedure II (Average Severity)	Procedure III (Max. Severity)
Temperature	Low Temp −55C	Low Temp −65C	Low temp −75C
	High Temp +71C	High Temp +85C	High temp +125C
Salt Spray (Fog)	No test	50 hr exposure	50 hr exposure
Sand and Dust	No test	Air Velocity 100 to 300 ft min. for 6 hours at 25C and at 71C	Air velocity 2300 ft/min for 6 hours at 25C and at 71C. Also air velocity 100 at 300 ft/min for 6 hours at 25C and at 71C.
Humidity	No test	5 twenty-four hour cycles	15 twenty-four hour cycles
Shock	No test	18 shocks of 11 ±1 milliseconds duration and a magnitude of 15 gs	18 shocks of 11 ±1 milliseconds duration and a magnitude of 30 gs
Vibration	10 to 55 cps	10 to 500 cps 1.5 to 10 gs	10 to 500 cps 1.5 to 30 gs
Electrolysis	No test	75 hours to 60 VDC	150 hours 120 VDC
Fungus	No test	5 types of fungi with a time duration of 28 days	5 types of fungi with a time duration of 28 days

Environmental Requirements—In order that the scope of the specification will be broad enough to cover PVRs in a variety of applications, the environmental requirements have been divided into three procedures each of a different degree of severity. It is not necessary that any one procedure be specified for all tests unless so specified by the purchaser. It is intended that a wide variety of PVRs could qualify and be built and used by ordering with reference to the applicable test procedures.

Solderability—Terminals shall be coated with approximately 0.00003 gold flash over silver plate, or equivalent finish to provide equal or better solderability and resistance to corrosion. The PVR's shall show no sign of mechanical damage and the resistance values shall not change by more than 0.25 percent when tested as per paragraph 4.6.11.

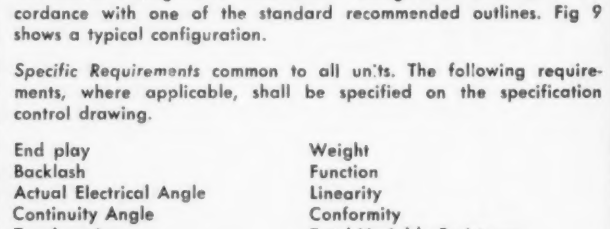
Mechanical Configuration—Mechanical configuration shall be in accordance with one of the standard recommended outlines. Fig 9 shows a typical configuration.

Specific Requirements common to all units. The following requirements, where applicable, shall be specified on the specification control drawing.

End play	Weight
Backlash	Function
Actual Electrical Angle	Linearity
Continuity Angle	Conformity
Tap Location	Total Variable Resistance
Maximum Applied Voltage	Built-in Resistance Values
Load Impedance	Resolution
Effective Tap Width	Stops
Power Rating	Degradation in Performance During Usable Life
Torque	Environmental Requirements

STANDARD DIMENSION,

NAS 710, STYLE RR-09 POTENTIOMETER



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SOmerset 6-5130

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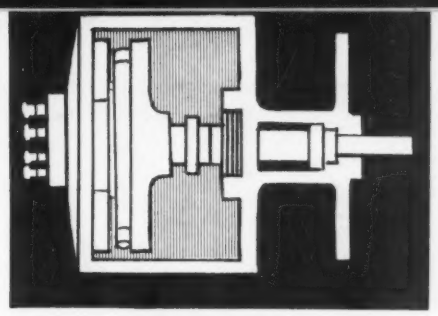
CIRCLE NO. 33 ON INQUIRY CARD

Status of Precision Wire-Wound Potentiometers



To survey the present state of the art in precision potentiometers, the editors of ELECTROMECHANICAL DESIGN sent a detailed questionnaire to leading manufacturers, requesting information on such important topics as accuracy, life, environmental requirements, standardization, and prospects for the future. The replies, evidencing a good deal of thought, provided details, amplifications and examples beyond the minimum requirements of the questions. This section summarizes the information received in question-answer form. Specific manufacturers are indicated only where sources are limited.

1. What are the highest accuracies (independent linearity) you can deliver in single or multi-turn potentiometers? (Wire-wound potentiometers only; see earlier discussion of film potentiometers for additional data.)
Summary of replies:

Diameter (inches)	Linear Pots Independent Linearity (±%) Single-Turn	Multi-turn	Sine-Cosine Pots Independent Conformity (±%)
½	0.5 to 1.0		
⅞	0.2 to 0.25	0.025 to 0.05	
1 1/16	0.2		
1½	0.15	0.02 to 0.025	
1⅞			0.25
2	0.1	0.02 to 0.025	
3	0.05 to 0.10		
8	0.01		0.05
10		0.002	

2. Some companies manufacture large diameter potentiometers having extremely high accuracies, better than ±0.01 percent. Are these accuracies maintained in use? How practical are such potentiometers?

Most manufacturers agreed that accuracies appreciably better than a hundredth percent can be achieved, but not all agreed that they can be maintained. Most remarked that they cannot be held in practical military and commercial applications during the life of the units, primarily due to the ageing of the parts resulting in minute dimensional instability, plus wear of the contacting surfaces. Where manufacturers claimed the practicability of these accuracies, they usually added the requirements of reduced shock and vibration specifications as well as restrictions on wire size, brush pressures, resolution, safety factors, and noise specifications. However, they indicated achievable life spans of 1,000,000 cycles in "not too severe" environments. Designs of these potentiometers, which are usually of large diameter or multi-turn requires exceptional concern with mechanical details. Analogue Controls, Inc., Litton Industries, and Colvern Ltd. who make extremely high-accuracy components expressed confidence in their practicality. However, very careful attention must be paid to operating conditions in specifying this type component.

3. What are the maximum temperatures your potentiometers can withstand without serious degradation of performance? Assume negligible dissipation.

SPECTROL—500°F in single-turn units, ±0.1 percent independent linearity. Working on multi-turn. No definite information on life.

CLAROSTAT—225°C, 500,000 cycles with 25 percent degradation.

DEJUR-AMSCO—150°C, 1,000,000 cycles, 40 cpm, ±0.3 percent.

MAUREY INSTRUMENT—250°C for small periods. 600°F unit in development.

GAMEWELL—150°C continuous, 200°C intermittent. Ratings are conservative, high temperatures feasible but not guaranteed as yet. No degradation.

TECHNOLOGY INSTRUMENT—150°C on all wire-wound units. Estimate 1000 hour life, 10^6 cycles, meeting all specifications as listed for room temperature.

CIRCUIT INSTRUMENTS—150°C, ±0.1 percent, 10^6 revolutions, 1000 hours. Units operated by some customers satisfactorily at 175°C.

CALBEST ELECTRONICS—450°F, 10^5 cycles, part time operation for 200 hours without damage or failure.

WATERS MANUFACTURING—150°C standard, with catalogue linearities.

ANALOGUE CONTROLS—200°C single-turn units, 125°C multi-turn. Life is 20 percent less than at 80°C. Inappreciable degradation of linearity.

ACCURACY—150°C at standard life and accuracy; reasonable periods at 200°C.

ACE ELECTRONICS—150°C units regularly produced without degradation of linearily. Degradation of equivalent noise resistance from 100 ohms max to 600 ohms max in 1000 hrs or 1 million cycles.

LITTON INDUSTRIES—200°C, 2000 hours non-operating. Index linearity ±0.05 percent.

HUMPHREY—400°F cont., 500°F intermittent., 10^6 cycles at room temperature, 25,000 cycles at peak temperature, best independent linearity ±0.1 percent.

4. What military or commercial standards are you frequently required to maintain?

Almost all the manufacturers listed NAS–710 and MIL-R-12934A as being the most commonly referenced specification for dimensions and performance. MIL-E-5272A was the most commonly referenced environmental spec.

5. General predictions for the future.

SPECTROL—No comment, Fifth Amendment.

CLAROSTAT—Reliabilities of 99.96 percent in the 20-40 million cycle range. Complete sealed construction. 50 gs to 5000 cps., wattages of 8-10 per inch diameter with linearities of 0.05 to 0.1 percent.

DEJUR-AMSCO—Smaller, hotter and tighter tolerances.

MAUREY INSTRUMENT—Ultra-high temperature tolerance and imperviousness to radiation damage. 1000°F. Radically new materials, obsoleting carbon and wire-wound types.

GAMEWELL—Smaller perhaps, but certainly hotter. New insulating materials required.

TECHNOLOGY INSTRUMENT—Metal film and conductive plastic types of resistance element with infinite resolution and hermetic sealing, more severe shock and vibration resistance. 3000 hour load life, temperatures to 250°-300°C, with specials to 500°C. Tighter linearities and noise specs.

CIRCUIT INSTRUMENTS—Operation to 250°C, more complete sealing, lighter and more rugged to meet more severe

push-pull
CONTROLS
Compression & Tension Type
Aircraft cable is strung with spherical steel shells in a rigid or flexible housing sealed with "O" rings. 3" standard bend radius. ¾" minimum bend radius.
Three Types:
1. Light Duty—Compression Ult. Load 1250 lbs.; Ult. tension 960 lbs.
2. Heavy Duty—Compression Ult. Load 1650 lbs.; Ult. tension 960 lbs.
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Photographed by means of a special process, it graphically illustrates the "snap" in Mueller's traditionally snappy springs. These springs provide a mean, corrosion-cutting bite for perfect test connections.

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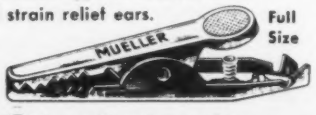

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CIRCLE NO. 35 ON INQUIRY CARD

shock and vibration requirements.

CALBEST ELECTRONICS—Temperatures to 800°F.

WATERS—Temperatures, 200°-500°C, 10 x 10^6 revolutions, minimum.

ANALOGUE CONTROLS — Potentiometers with "linearities available today in temperature ranges from −65°C to +125°C will be feasible in temperatures of −100°C to +500°C."

LITTON—Greater reliability and life during more severe environmental conditions. Answer is in better materials and improving present techniques.

HUMPHREY—Higher temperature, less wear and noise under all environmental conditions.

GIANNINI—Hydraulic oil-filled pots for hydraulic pressure systems to withstand extreme environments.

ACE ELECTRONICS—Higher temperature operation, new conductive materials and new wire alloys with superior characteristics.

INTERPRETING CHARTS CD-II

Many manufacturers have entered the potentiometer field because of its broad scope and the great variety of types required in industry. While some large companies have a complete line covering most of the types required, smaller ones frequently specialize in some segment of the field.

In interpreting these component charts, it is important to exercise caution, inasmuch as the many manufacturers, each with his own nomenclature, may have presented their data in somewhat different fashion. This is an unfortunate consequence of lack of standardization. Some manufacturers present data in a conservative manner, keeping in mind the desirability of low rejection rates and feasible production requirements. Others, concerned with specialized types, perhaps used in small quantities, present more marginal limits. The charts can never be more than suggestive of accuracies being attained in the field today. Users of a precision potentiometer must make their selections by direct negotiation with manufacturers. The chart does not cover every variety of pot by every manufacturer. Rather, some of the larger manufacturers are listed with nearly complete description of their line. These lines have, over a long time, developed the reputation of being good and their performance may be regarded as being, to a large extent, representative. While it is true that products of individual manufacturers making more specialized types might outperform the products listed in the table, we feel that the table will give a starting point for further investigation.

BIBLIOGRAPHY

1. *Environmental Effects on Precision Potentiometers*, Albert W. Green and Keith S. Schulz, Helipot Corp., presented at the Western Electronics Convention, 1956.
2. *Precision Potentiometer Life and Reliability*, H. H. Houdyshell, Helipot Corp., presented at the Electronics Components Conference, 1955.
3. *Measurements and Correction of Phase Shift in Copper-Mandrel Precision Potentiometers*, Stanley Schneider, Fred Hiraoka, and Clarence Gaudlin, Helipot Corp., 1957.
4. *A Symposium of Technical Articles*, obtainable from Borg Equipment Division, The George W. Borg. Corp.
5. *A Guide to Applying Resistance Pots*. Hollis L. Gray, Jr., Technology Instrument Corp., reprinted from *Control Engineering*, July, 1956.
6. *T. I. C. Potentiometers Handbook*, published by Technology Instrument Corp., provides an excellent overall treatment on the subject of precision potentiometers.
7. *Electrical Noise on Wire-Wound Potentiometers*, Irving T. Hogan, Helipot Corp., presented at the 1952 West Coast IRE.
8. *Use of Taps to Compensate Pot Loading Errors*, Gilbert, *Control Engineering*, Aug. 1956.
9. *How to Phase Compensate Loaded Pots*, J. Gilbert, *Control Engineering*, Jan. 1957.
10. *Computing with Servo-Driven Potentiometers*, F. R. Bredley, R. D. McCoy, *Electronic Industries*, Sept. 1952.

Note: particularly broad coverage is given in TIC Handbook and Helipot—Article Series.

These engineers are checking data as it is being acquired from a dynamic test. The results are being recorded on an oscillograph equipped with CEC's rapid-access DATARITE Magazine . . . DATARITE produces a flash-processed, dried, fully visible and permanent oscillogram in less than a second!

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In the test set up above, a DATARITE oscillograph and magnetic-tape recorder/reproducer are being operated in a time-parallel circuit. Input data fed to the tape unit are simultaneously recorded and processed by the DATARITE Magazine. Therefore, test results may be monitored continuously. Notations pertinent to the test, or references to later data-processing operations of the tape may be made directly on the DATARITE record as it emerges.

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CHART CD-II—1

SUMMARY OF PRECISION WIRE WOUND POTENTIOMETERS MECHANICAL AND ELECTRICAL CHARACTERISTICS

CHARACTERISTICS	DIMENSIONS						
1 Diameter	inches	0.5	0.5	0.5	0.5	0.5	0.5
2 No. of Turns	....	1	1	1	1	1	1
3 Mfr. (See Buyers' Guide)	....	Wat	Wat	Wat	Ace	Ace	DeJ
4 Model No.	....	AP ½[1]	APH ½[2]	APD ½	500	X500	C-050
5 Length	inches	0.375	0.468	0.5	0.571	0.571	0.563
6 Length add'l cups	inches	....	....	....	....	....	....
7 Weight	oz.	¼	½	½	¼	¼	....
8 Mount (Servo or Bushing)	....	B	Solder	Plug in	S or B	S or B	S or B
9 Housing Material	....	alum.	Brass	alum.	alum.	alum.	Ni pl. Bronze
10 Shaft Diameter	inches	⅛	....	....	0.1245	⅛	0.1246
11 Starting Friction	oz-inches	....	....	....	....	....	....
12 Mech. Travel (total)	degrees	320	cont.	320	cont.	cont.	cont.
13 Mech. Travel (tolerance)	degrees	±5	....	±5	....	....	....
14 Elec. Travel (total)	degrees	320	340	320	325	325	320
15 Elec. Travel (tolerance)	degrees	±5	±10	±10	±2	±2	±5
16 Moment of Inertia	Gm Cm²	....	....	....	....	....	....
17 Maximum Taps	....	....	....	....	....	....	....
18 Overtravel	degrees	....	....	....	....	....	....
19 Ind. Linearity (Conformity) Stand.	%	3	±3	3	±0.3	±0.3	±1
20 Ind. Linearity (Conformity) Spec.	%	....	....	....	....	....	±0.3
21 Resolution (max.)	%	....	....	....	....	....	....
22 Resistance min.	ohms	50	½	½	10	10	....
23 Resistance max.	K ohms	100	100	250	250	250	....
24 Ambient temp. (max.) stand.	degrees C	125	150	100	125	50	....
25 Ambient temp. (max.) spec.	degrees C	....	....	....	....	....	....
26 Resistance Tolerance Stand.	%	5	±5	±5	±2	±2	±5
27 Resistance Tolerance Spec.	%	....	....	....	....	....	±1
28 Power at degrees C	Watts	2/60	1.5/25	1/40	2/60 rise	2/60 rise	1.5/60 rise
1 Diameter	inches	0.875	0.875	0.875	0.875	0.875	0.875
2 No. of Turns	....	1	1	1	1	10	10
3 Mfr. (see Buyers' Guide)	....	Hel	Cir	Kin	Rat	Tec	Hel
4 Model No.	....	....	B-14	1000A[3]	087	C10-09	AJ
5 Length	inches	0.75	0.776	0.796	0.803	1.457	1.5
6 Length add'l cups	inches	....	0.570	0.469	....	1.161	....
7 Weight	oz.	0.6	0.5	0.6	....	2	1
8 Mount (Servo or Bushing)	....	S or B	S	S	S	S	S or B
9 Housing Material	....	....	alum.	alum.	alum.	....	....
10 Shaft Diameter	inches	⅛	⅛	⅛	⅛	....	⅛
11 Starting Friction	oz-inches	0.050	0.1	0.1	0.2	0.20	1
12 Mech. Travel (total)	degrees	cont.	cont.	cont.	cont.	3600	3600
13 Mech. Travel (tolerance)	degrees	....	....	....	....	+10-0	+10-0
14 Elec. Travel (total)	degrees	354	350	358	340	3600	3600
15 Elec. Travel (tolerance)	degrees	±2	±2	±1	±2	±0.5	+10-0
16 Moment of Inertia	Gm Cm²	0.12	2.5	....	....	....	0.3
17 Maximum Taps	....	9	avail.	6	3	48	32
18 Overtravel	degrees	....	....	....	....	....	....
19 Ind. Linearity (Conformity) Stand.	%	±0.5	±0.5	±0.2	±1	±0.05	±0.5
20 Ind. Linearity (Conformity) Spec.	%	±0.25	±0.25	....	±0.3	±0.03	±0.1
21 Resolution (max.)	%	....	....	0.08	0.07	....	....
22 Resistance min.	ohms	1000	....	10	....	1000	25
23 Resistance max.	K ohms	100	50	100	20	150	100
24 Ambient temp. (max.) stand.	degrees C	105	150	65	110	150	80
25 Ambient temp. (max.) spec.	degrees C	....	....	225	....	....	....
26 Resistance Tolerance Stand.	%	±5	±5	±5	±5	±5	±5
27 Resistance Tolerance Spec.	%	±2	±2	±2	±2	±2	±2.5
28 Power at degrees C	Watts	1.5	1/100	2/160	1/25	....	2.8/40

FOOTNOTES: *1. Hermetically sealed. 2. Dial faced.*

CHART CD-II—1 (cont.)

SUMMARY OF PRECISION WIRE WOUND POTENTIOMETERS MECHANICAL AND ELECTRICAL CHARACTERISTICS

CHAR.										
1	0.625	0.75	0.75	0.75	0.875	0.875	0.875	0.875	0.875	0.875
2	1	1	1	1	1	....	1	1	1	1
3	Pre	Elm	Mau	Mau	Pre	DeJ	Osb	Cla	Tec	Gia
4	R6	M-1	75M7	75M30	R9	C-078	09	54-14[3]	LT09	875T
5	0.656	0.62	0.75	0.75	0.375	0.5	0.625	0.671	0.730	0.75
6	....	....	....	....	3/8	....	0.478	0.375	0.380	0.5
7	....	3/4	....	....	....	1/2	0.6	0.5	0.3	5/8
8	S	S or B	B	B	B	S	S or B	S or B	S	S
9	alum.	alum.	alum.	alum.	alum.	alum.	alum.	....	....	alum.
10	1/8	0.250	1/8	1/4	1/4	0.1246	0.1248	1/8	....	1/8
11	....	....	0.2	....	....	....	0.05	0.5	0.1	0.1
12	320	cont.	cont.	340	320	cont.	cont.	cont.	as req'std	cont.
13	....	....	....	....	±5	....	....	....	....	....
14	320	330	315	315	310	320	354	320	350	320
15	±3	±5	±3	±3	±5	±2	+0-2	....	±0.5	±2
16	....	....	....	....	....	....	0.15	1.5	....	....
17	....	none	....	....	....	....	9	....	7	4
18	....	....	....	....	....	....	....	....	....	....
19	±0.5	±1	±1	±1	±0.035	±1	±0.5	±1	±0.5	±0.5
20	±0.2	....	±0.5	±0.5	±0.17	....	....	±0.25	±0.3	±0.2
21	....	Standard	....	....	....	....	....	0.06	....	0.06
22	100	100	25	25	100	....	10	....	30	200
23	30	25	100	50	50	....	20	20	125	100
24	85	100	125	125	85	....	125	125	150	....
25	125	....	....	....	125	....	....	....	....	200
26	±5	±5	±5	±5	±5	±5	±3	±5	±5	±5
27	....	....	....	....	....	±1	....	±1	±2	....
28	1/80	2.5/25	2/40	2/40	2/80	2/25	1.25/25	2/40	....	2/25

1	0.875	0.875	0.875	0.875	1	1	1	1	1	1
2	10	10	10	10	1	1	1	1	10	10
3	Lit	Cla	Spe	Fai	Fer	Hub	Gia	Gia	Hub	Fai
4	MD 09-10	....	500	908	Type 11	11	85111[4]	85151[4]	101	920
5	1.5	1.568	1.573	1.583	0.718	0.734	1.31	1.31	1.297	2.435
6	....	....	1.448	....	0.28	....	....	....	....	....
7	1.25	1.1	1	1	3/4	0.95	0.6	0.6	1.43	2.5
8	S	S or B	S or B	S	S	....	....	....	....	S or B
9	alum.	....	phenolic	alum.	alum.	....	mold. plas.	mold. plas.	....	alum.
10	0.1248	....	0.1248	1/8	0.078	0.1248	0.031	0.125	0.1248	0.250
11	0.3	0.6	0.4	0.75	0.007	1	....	....	1	1
12	3785	3600	3600	3600	....	360	cont.	cont.	3600	3600
13	....	+5-1	+5-0	+10-0	....	±5	....	....	±5	+4-0
14	3600	3600	3600	3600	340	360	360	360	3600	3600
15	+1-0	+5-1	+5-0	+10-0	....	±5	±5	±5	±5	+2-0
16	....	1.7	0.45	....	....	....	0.035	....	....	....
17	many	20 max.	46	100	avail.	....	....	....	....	many
18	....	....	....	....	....	....	....	....	....	....
19	±0.1	±0.25	±0.3	±0.05	±0.5	±0.5	±0.5	±0.5	±0.5	±0.25
20	±0.015	±0.05	±0.025	....	....	±0.3	....	....	±0.05	±0.05
21	....	0.005	....	....	0.05	0.007	0.05	0.05	0.007	....
22	....	....	25	100	1000	10	100	100	25	1000
23	....	100	250	100	50	10	100	100	100	1000
24	85	125	105	85	70	85	100	100	85	150
25	150	....	125	....	....	....	150	150	....	....
26	±5	±5	....	±5	±5	±5	....	....	±5	±5
27	....	....	....	....	....	....	....	....	....	....
28	25/40	3/40	2.75/40	2.5/40	....	1/40	1.63/25	1.63/25	3/40	3.5/85

FOOTNOTES: *3. Dynamically balanced. 4. Very low torque unit.*

CHART CD-II–2

SUMMARY OF PRECISION WIRE WOUND POTENTIOMETERS MECHANICAL AND ELECTRICAL CHARACTERISTICS

CHARACTERISTICS	DIMENSIONS						
1 Diameter	inches	1.005	1.063	1.063	1.125	1.125	1.125
2 No. of Turns	....	10	1	1	1	1	1
3 Mfr. (See Buyers' Guide)	....	Voa	Tec	Kin	Spe	Wat	Fai
4 Model No.	....	AV	LT11	1000B[1]	110	AP 1⅛	741 C
5 Length	inches	1.830	0.730	0.796	0.475	0.5	0.685
6 Length add'l cups	inches	....	0.380	0.469	0.350	....	....
7 Weight	oz.	1.6	0.5	0.75	0.9	¾	0.77
8 Mount (Servo or Bushing)	....	B	S	S	S or B	B	S or B
9 Housing Material	....	Alum.	....	Alum.	alum.	alum	alum.
10 Shaft Diameter	inches	¼	....	⅛	....	0.2500	⅛
11 Starting Friction	oz-inches	0.7	0.1	0.1	0.35	....	0.25
12 Mech. Travel (total)	degrees	3600	as req.	cont.	cont.	320	cont.
13 Mech. Travel (tolerance)	degrees	+3-0	....	....	....	±5	....
14 Elec. Travel (total)	degrees	3600	350	358	354	320	350
15 Elec. Travel (tolerance)	degrees	+2-0	±0.5	±1	-0-2	±5	....
16 Moment of Inertia	Gm Cm²	....	....	....	0.12	....	....
17 Maximum Taps	....	....	9	8	9	....	13
18 Overtravel	degrees	....	....	....	....	....	....
19 Ind. Linearity (Conformity) Stand.	%	±0.3	±0.5	±0.2	±0.5	2	±0.5
20 Ind. Linearity (Conformity) Spec.	%	±0.025	0.3	....	±0.2	....	±0.25
21 Resolution (max.)	%	....	....	0 06	....	....	0.05
22 Resistance min.	ohms	100	30	10	20	50	300
23 Resistance max.	K ohms	300	150	130	175	100	150
24 Ambient temp. (max.) stand.	degrees C	150	150	....	105	125	150
25 Ambient temp. (max.) spec.	degrees C	avail.	....	....	125	....	....
26 Resistance Tolerance Stand.	%	±0.5	±5	±5	....	±5	±5
27 Resistance Tolerance Spec.	%	....	±2	±2	....	....	....
28 Power at degrees C	watts	3/90	....	2/160	2/40	4/60	2/40

1 Diameter	inches	1.5	1.625	1.656	1.75	1.75	1.750
2 No. of Turns	....	10	1	1	1	1	1
3 Mfr. (See Buyers' Guide)	....	Cir	DeJ	Fai	Hel	GeR	Cir
4 Model No.	....	HD-150	C-158	736	....	973	2800
5 Length	inches	2	0.960	0.789	0.8	.813	0.890
6 Length add'l cups	inches	....	....	0.609	....	....	0.468
7 Weight	oz.	2.6	....	3.25	2.75	1	3
8 Mount (Servo or Bushing)	....	....	S or B	....	S	....	S
9 Housing Material	....	phenolic	alum.	phenolic	....	phenolic	phenolic
10 Shaft Diameter	inches	0.250	¼	0.2500	¼	0.375	¼
11 Starting Friction	oz-inches	2	....	....	1.5	....	0.40
12 Mech. Travel (total)	degrees	3600	cont.	cont.	cont.	330	cont.
13 Mech. Travel (tolerance)	degrees	+4-0	....	....	....	±5	....
14 Elec. Travel (total)	degrees	3600	320	340	320	320	350
15 Elec. Travel (tolerance)	degrees	+4-0	±3	....	±1	±5	±2
16 Moment of Inertia	Gm Cm²	5.2	....	....	6.5	....	3.8
17 Maximum Taps	....	....	....	9	4	....	avail.
18 Overtravel	degrees	....	....	....	....	....	....
19 Ind. Linearity (Conformity) Stand.	%	±0.5	±0.5	±0.5	±0.5	±1	±0.5
20 Ind. Linearity (Conformity) Spec.	%	....	0.3	0.35	±0.25	....	0.1
21 Resolution (max.)	%	to 0.0036	....	0.05	....	....	....
22 Resistance min.	ohms	100	....	500	100	5	....
23 Resistance max.	K ohms	600	....	200	125	50	330
24 Ambient temp. (max.) stand.	degrees C	100	....	85	80	....	150
25 Ambient temp. (max.) spec.	degrees C	....	....	....	....	....	....
26 Resistance Tolerance Stand.	%	±5	±5	±5	5	±5	±5
27 Resistance Tolerance Spec.	%	±0.5	±1	....	±1	....	....
28 Power at degrees C	watts	5/40	3/60	3.0/40	3.4	5/25	3/100

FOOTNOTE: *1. Dynamically balanced.*

CHART CD-II—2 (cont.)

SUMMARY OF PRECISION WIRE WOUND POTENTIOMETERS MECHANICAL AND ELECTRICAL CHARACTERISTICS

CHAR.										
1	1.125	1.25	1.25	1.438	1.438	1.438	1.44	1.5	1.5	1.505
2	1	1	1	1	1	10¼	1	1	10	10
3	Wat	Gam	GeR	Spe	Tec	Spe	Rat	Fer	Gia	Voa
4	WPSC 1-⅛	RL 270A-1¼	972	170	LT15	870	143	15	85175[2]	RV
5	0.688	0.625	1.0625	0.805	1.090	2.187	0.975	0.680	1.5	1.83
6	....	0.375	....	0.565	0.520	....	....	0.41	....	....
7	1	1	¾	2.2	1.0	3.8	....	1.5	2.1	2.6
8	S	S or B	....	S or B	S	S	S	S	B	B
9	alum.	Non-metal	phenolic	alum.	....	plastic	alum.	alum.	alum.	alum.
10	0.2500	....	0.250	0.2497	....	0.2497	0.2500	⅛	....	¼
11	....	....	....	0.62	0.15	0.9	0.4	0.06	2	0.7
12	cont.	....	330	cont.	....	3690	cont.	....	3600	3600
13	....	....	±5	....	....	+3-0	....	....	+5-0	+3-0
14	360	350	320	352	350	3600	340	340	....	3600
15	....	±1.5	±5	±2	±0.4	+3-0	±1	....	....	+2-0
16	....	....	....	1.0	....	12	....	....	....	....
17	....	14	....	15	17	91	9	avail.	....	....
18	....	....	....	....	....	....	....	....	....	....
19	....	±0.25	±2	±0.5	±0.4	±0.3	0.5	0.3	±0.1	±0.3
20	....	....	....	±0.15	0.2	±0.02	2	....	±0.05	±0.025
21	....	....	....	....	....	....	0.048	to 0.05	infinite	....
22	....	20	5	10	50	30	....	500	20	100
23	20	65	50	60	250	750	110	100	2500	300
24	—125	150	....	105	150	125	11	70	71	150
25	....	....	....	125	....	....	....	....	....	avail.
26	±5	±5	±5	....	±5	....	5	±5	....	0.5
27	....	....	....	....	±2	....	1	....	....	....
28	4/60	2.25/85	5/25	2.75/40	....	7/40	2.0/40	....	1.5/71	5/90

1	1.75	1.75	1.75	1.75	1.758	1.758	1.758	1.758	1.812	1.875
2	1	1	1	1	3	10	10	10	3	1
3	Hel	Gia	Gia	Tec	Hel	Hel	Spe	Fai	Rat	Osb
4	....	1750	1750-21[3]	LT 18	....	....	800	930	181-3	20
5	1	1.047	1.047	1.090	1.141	1.984	1.984	2.113	1.44	0.625
6	....	....	....	0.520	....	....	1.997	....	....	0.555
7	3	2.8	2.8	1.5	2.5	4.5	4.5	5	....	2.5
8	S or B	S	S	S	B	S or B	S or B	S or B	S	S or B
9	....	alum.	alum.	....	....	....	phenolic	alum.	alum.	alum.
10	¼	¼	¼	....	¼	¼	0.2497	¼	0.2500	0.2497
11	1.5	0.5	0.5	0.15	1.8	1.3	1.2	1.25	1.0	0.9
12	cont.	cont.	cont.	as req.	1080	3600	3600	3600	1080	cont.
13	....	....	....	....	+4-0	+1-0	+3-0	+1-0	+1-0	....
14	354	356	360	350	1080	3600	3600	3600	1080	356
15	±1	±1	....	±0.4	+4-0	+1-0	+3-0	+1-0	+1-0	±10
16	2.5	2.4	....	....	7	22	15	30	....	1.4
17	17	25	....	17	14	28	111	many	5	25
18	....	....	....	....	....	....	....	....	....	....
19	±0.5	±0.3	1	±0.3	±0.5	±0.5	±0.3	±0.1	0.10	±0.3
20	....	±0.1	....	0.15	±0.1	0.025	±0.020	±0.025	0.05	....
21	....	±0.02	....	....	....	....	....	....	0.017	....
22	5	10	....	50	5	50	50	1000	....	20
23	65	300	20	310	130	400	1000	2000	100	75
24	80	105	105	150	80	80	105	....	110	125
25	....	150	....	....	....	....	125	150	....	....
26	±5	....	....	±5	±5	±5	....	5	5	±3
27	±1	....	....	±2	±1	±1	....	0.2	1	....
28	3.4	3.5/40	3.5/40	....	4.1	6.9	6.9/25	5/85	5.0/40	3.5/25

FOOTNOTES: *2. Spiralpot for infinite resolution. 3. Sine-cosine pnit.*

CHART CD-II—3

SUMMARY OF PRECISION WIRE WOUND POTENTIOMETERS MECHANICAL AND ELECTRICAL CHARACTERISTICS

CHARACTERISTICS	DIMENSIONS						
1 Diameter	inches	1.875	1.875	1.875	2	2	2
2 No. of Turns	....	1	3	10	1	1	1
3 Mfr. (See Buyers' Guide)	....	Kin	Elm	Elm	Gam	Spe	Ana
4 Model No.	....	1000C[1]	E-3	E-10	RL270A-2	300	D 1801
5 Length	inches	0.889	1 19/32	2 1/16	0.625	0.805	0.813
6 Length add'l cups	inches	0.562	....	....	3/8	0.565	....
7 Weight	oz.	1.5	3.9	5.1	3	3.802	....
8 Mount (Servo or Bushing)	....	S	S or B	S or B	S or B	S or B	....
9 Housing Material	....	alum.	....	....	non-metal	alum.	....
10 Shaft Diameter	inches	1/4	0.2500	0.2500	1/4	0.2497	....
11 Starting Friction	oz-inches	0.25	1.3	1.3	....	1.0	0.75
12 Mech. Travel (total)	degrees	cont.	1080	3600	....	cont.	cont.
13 Mech. Travel (tolerance)	degrees	....	+1-0	+1-0	....	....	....
14 Elec. Travel (total)	degrees	358	1080	3600	355	356	356
15 Elec. Travel (tolerance)	degrees	±1	+1-0	+1-0	±1	±1	±1
16 Moment of Inertia	Gm Cm^2	....	18	20	....	1.0	6
17 Maximum Taps	....	12	8	8	26	21	....
18 Overtravel	degrees	....	....	....	....	....	....
19 Ind. Linearity (Conformity) Stand.	%	±0.1	±0.05	±0.015	±0.15	±0.3	±0.1
20 Ind. Linearity (Conformity) Spec.	%	....	....	....	....	±0.1	±0.075
21 Resolution (max.)	%	0.04	....	....	....	....	....
22 Resistance min.	ohms	20	500	500	35	20	....
23 Resistance max.	K ohms	200	75	200	150	135	....
24 Ambient temp. (max.) stand.	degrees C	....	100	100	150	105	95
25 Ambient temp. (max.) spec.	degrees C	225	....	....	....	125	....
26 Resistance Tolerance Stand.	%	±5	±5	±5	±5	....	±5
27 Resistance Tolerance Spec.	%	±2	....	....	....	....	....
28 Power at degrees C	watts	2.5/160	3.75/25	6.25/25	4/80	5/40	5/60

1 Diameter	inches	2	2.313	2.875	3	3	3
2 No. of Turns	....	20	....	1	1	1	1
3 Mfr. (See Buyers' Guide)	....	Lit	Gam	Osb	Spe	Cir	Cla
4 Model No.	....	MD20-20[2]	RL11C	30	400	4800	....
5 Length	inches	2-9/16	1.513	0.625	0.805	0.890	1
6 Length add'l cups	inches	....	....	0.555	0.565	0.468	....
7 Weight	oz.	8	4.75	4.5	7	6.5	4.5
8 Mount (Servo or Bushing)	....	S	....	S or B	S or B	S	S or B
9 Housing Material	....	....	....	alum.	alum.	phenolic	....
10 Shaft Diameter	inches	1/4	0.1875	0.2497	0.2497	1/4	....
11 Starting Friction	oz-inches	1.5	....	1	1.1	0.40	1.0
12 Mech. Travel (total)	degrees	7385	cont.	cont.	cont.	cont.	cont.
13 Mech. Travel (tolerance)	degrees	+5-4	....	....	....	....	....
14 Elec. Travel (total)	degrees	7200	....	358	358	350	340
15 Elec. Travel (tolerance)	degrees	+1-0	....	±1	±1	±2	....
16 Moment of Inertia	Gm Cm^2	40	....	1.5	10.0	38	.8
17 Maximum Taps	....	....	....	37	37	avail.	.....
18 Overtravel	degrees	....	....	....	....	....	....
19 Ind. Linearity (Conformity) Stand.	%	±0.05	±0.6	±0.3	±0.3	±0.5	0.3
20 Ind. Linearity (Conformity) Spec.	%	0.0075	....	....	±0.05	±0.1	0.15
21 Resolution (max.)	%	....	0.40	....	....	....	0.015
22 Resistance min.	ohms	1000	....	100	100	....	....
23 Resistance max.	K ohms	600	16	100	220	600	200
24 Ambient temp. (max.) stand.	degrees C	85	....	125	105	150	125
25 Ambient temp. (max.) spec.	degrees C	125	....	....	125	....	....
26 Resistance Tolerance Stand.	%	±5	±10	±3	....	±5	±5
27 Resistance Tolerance Spec.	%	±1	....	....	....	±1	±1
28 Power at degrees C	watts	4/85	....	5/25	7/40	6/100	6.1/40

FOOTNOTES: *1. Dynamically balanced. 2. Aluminum hub.*

CHART CD-II—3 (cont.)

SUMMARY OF PRECISION WIRE WOUND POTENTIOMETERS
MECHANICAL AND ELECTRICAL CHARACTERISTICS

CHAR.										
1	2.0	2	2.0	2	2	2	2	2	2	2
2	1	1	1	1	1	1	1	10	10	15
3	Cir	Hel	Cla	Mic	Tec	Mau	Nor	Lit	Ana	Ana
4	3200	....	....	C400	LT20	200M30	....	MD20-10[2]	F1810	N1815
5	0.890	0.969	1.0	1.000	1.090	1.313	....	1 25/32	2	2 33/64
6	0.468	....	....	0.969	0.520	13/16	....	....	....	....
7	3.5	4	3	2.5	2	....	....	6	....	....
8	S	S or B	S or B	univ'l	S	S	S or B	S	....	....
9	alum.	....	....	alum.	....	alum.	alum.	....	....	....
10	1/4	1/4	....	....	....	1/4	1/4	1/4	....	....
11	0.40	1	1.0	0.6	0.18	1	0.25	1	0.75	0.75
12	cont.	cont.	cont.	cont.	....	cont.	cont.	3785	3780	5580
13	....	....	....	....	....	....	....	....	±4	±4
14	350	356	340	320	350	320	360	3600	3600	5400
15	±2	±10	....	±1	±0.25	±1	....	+1-0	+1-0	+1-0
16	10	14	5	....	....	....	....	20	19	30
17	avail.	21	....	50	17	30	40	many	....	....
18	....	....	....	....	....	....	....	....	....	....
19	±0.5	±0.5	±0.5	±0.35	±0.2	±0.5	±0.1	±0.1	±0.02	±0.01
20	±0.1	±0.15	±0.15	....	±0.1	±0.2	....	±0.01	±0.01	±0.1
21	....	....	0.025	....	....	....	....	....	....	....
22	....	5	....	100	100	50	100	1000	....	....
23	400	75	140	500	355	200	100	300	....	400
24	150	80	125	80	150	85	125	85	95	150
25	....	....	....	....	....	....	....	125	....	....
26	±5	±5	±5	±1	±5	±5	....	±5	±5	±5
27	±1	±1	±1	....	±1	±1	....	±1	....	±1
28	4.5/100	5.5	5.5/40	4/40	....	5/25	....	5/85	5/60	4.5/100

1	3	3	3	3	3	3	3	3	3.313	4.375
2	1	1	1	1	1	1	10	15	15	....
3	DeJ	Hel	DeJ	Tec	Fai	Fai	Lit	Ana	Hel	Gam
4	C 300	....	360	LT30	743	753[3]	MA30-10	J 3015	....	RL14MS[3]
5	1 1/4	1	1.062	1.090	1.173	1.405	2.266	2 3/4	2 7/8	4.313
6	....	....	....	0.520	0.580	0.812	....	....	....	....
7	....	5.8	4	3	5.5	9	14	....	13	29
8	S or B	S or B	S	S	S	....	S	....	S or B	....
9	alum.	....	bakelite	....	....	alum.	....	....	....	....
10	0.2499	1/4	1/4	....	0.250	0.250	0.250	....	1/4	0.250
11	....	1.5	....	0.18	....	....	2.0	1.75	2.75	....
12	cont.	cont.	cont.	as req.	cont.	cont.	3785	5580	5400	cont.
13	....	....	....	....	....	....	....	±4	+4-0	....
14	cont.	358	315	350	356	360	3600	5400	5400	....
15	....	±1	±3	±1/4	....	....	+1-0	+1-0	+4-0	....
16	....	55	....	....	....	....	60	175	200	....
17	....	33	....	27	20	....	....	....	80	....
18	....	....	....	....	....	....	....	....	....	....
19	±1	±0.5	±1	0.1	±0.01	±0.35	±0.0075	±0.01	0.5	±0.5
20	....	±0.1	....	....	±0.075	....	....	±0.005	0.025	....
21	....	....	....	....	....	....	....	....	....	0.20
22	....	5	....	100	1000	500	2000	....	40	....
23	....	100	....	575	650	45	300	....	1000	35.4
24	....	+80	....	150	85	85	85	95	80	....
25	....	....	....	....	....	....	....	....	....	....
26	±10	±5	±5	±5	....	....	±5	5	±5	±1
27	±5	±1	±1	±1	....	....	±1	....	±1	....
28	4/25	6.9	8/25	....	8/40	8/40	8/40	12/60	13.8	....

FOOTNOTES: *2. Aluminum hub. 3. Sine-cosine unit.*

Sensitive DIFFERENTIAL PRESSURE and VACUUM CONTROLS

J6K
J27KB

By using **UNITED ELECTRIC's** Type J6K or Type J27KB control, it is possible to control accurately the difference in pressure between two pressure or vacuum sources. The J6K contains a single switch; the J27KB is a dual switch control.

System Differential	Up to 90 psi.
Switch Differential	J6K — can be set between limits of ½" Hg and 3 psi. J27KB — can be set between limits of 1" Hg and 5 psi.
Switch Ratings	15 amps. at 115 or 230 volts A.C. Also 20 amps. or D.C. switches on specification.
Switch Types	N.O., N.C., or Double Throw — no neutral position.
Adjustments	J6K — internally located, uncalibrated adjustment wheel. J27KB — each switch has independent, uncalibrated adjustment screw.
Electrical Connections	Made to screw terminals on switches through clearance hole in enclosure.
Pressure Connections	Two ¼" female NPT pressure connections.
Size	J6K — 7 5/32" x 4 27/32" x 2 5/16". J27KB — 7 1/16" x 6 1/8" x 2 7/8".
Approximate Weight	J6K — 2¼ lbs. J27KB — 2 lbs.

UNITED ELECTRIC *manufactures a complete line of temperature, pressure and vacuum controls. Standard units can be modified or custom-built units made to your specifications. Additional information on pressure and vacuum controls is available upon request.*

UE® United Electric Controls COMPANY
91 SCHOOL STREET, WATERTOWN, MASS

CIRCLE NO. 37 ON INQUIRY CARD

BUYERS' GUIDE for PRECISION POTS

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4 Gordon St., Waltham, Mass.

ACE ELECTRONICS ASSOCIATES
99 Dover St., Somerville 44, Mass.

ANALOGUE CONTROLS, INC.
39 Roselle St., Mineola, N.Y.

BORG EQUIPMENT DIV.—The George W. Borg Corp.
120 S. Main St., Janesville, Wisconsin

BOURNS LABORATORIES, INC.
P.O. Box 2112, Riverside, Cal.

CALBEST ELECTRONICS CO.
4801 Exposition Blvd., Los Angeles 16, Cal.

CARTER MFG. CORP.
23 Washington St., Hudson, Mass.

CIRCUIT INSTRUMENTS, INC.—Div.—International Resistance Co.
P.O. Box 1438, St. Petersburg, Fla.

CLAROSTAT MFG. CO., INC.
Dover, N.H.

COLVERN LTD.—British Radio Electronics, Ltd.
1833 Jefferson Pl. N.W., Washington 6, D.C.

COMPUTER INSTRUMENTS CORP.
92 Madison Ave., Hempstead, N.Y.

DALE PRODUCTS, INC.
Box 136, Columbus, Nebraska

DAYSTROM PACIFIC—Div.—Daystrom, Inc.
9320 Lincoln Blvd., Los Angeles 45, Cal.

DEJUR—AMSCO CORP.
Northern Blvd. at 45th St., L.I.C. 1, N.Y.

ELECTRO-MEC LABORATORY, INC.
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ELECTROMATH CORP.
42-14 Greenpoint Ave., L.I.C. 4, N.Y.

ELEKTRO-SERV. CO.
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FAIRCHILD CONTROLS CORP.—Components Div.
225 Park Ave., Hicksville, N.Y.

FERRANTI, LTD.
Ferry Rd., Edinburgh 5, England

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1238 Chestnut St., Newton Upper Falls 64, Mass.

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GENERAL RADIO CO.
275 Mass. Ave., Cambridge 39, Mass.

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Newport Beach, Cal.

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LITTON INDUSTRIES
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MARKITE CORP.
155 Waverly Place, New York 4, N.Y.

MAUREY INSTRUMENT CORP.
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MICRO-LECTRIC
Roosevelt, Long Island, N.Y.

MINIATURE ELECTRONIC COMPONENTS CORP.
Holbrook, Mass.

NORDEN-KETAY CORP.—Precision Components Div.
Commack, N.Y.

OSBORNE ELECTRIC CORP.
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PERKIN-ELMER CORP.
768 Main Ave., Norwalk, Conn.

PRECISION LINE, INC.
63 Main St., Maynard, Mass.

GEORGE RATTRAY & CO., INC.
116-08 Myrtle Ave., Richmond Hill, N.Y.

SERVOMECHANISMS, INC.—Special Products Div.
12500 Aviation Blvd., Hawthorne, Cal.

SPECTROL—Div. of Carrier Corp.
1704 S. DelMar, San Gabriel, Cal.

TECHNOLOGY INSTRUMENT CORP.
533 Main St., Acton, Mass.

VOAK ENGINEERING CO.
129 "A" St., Upland, Cal.

WATERS MFG., INC.
Boston Post Rd., Wayland, Mass.

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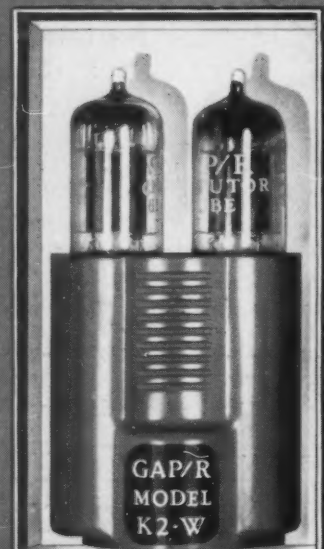
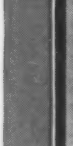
PLUG FOR ANALOG



FAST DC AMPLIFIER: Model K2W is an efficient and foolproof high-gain operational unit for all feedback computations, fast and slow. A number of special varieties are also in quantity production. ($24.00)



SLOW DC AMPLIFIER: Model K2-P offers long-term sub-millivolt stability, either by itself or in tandem with the K2-W. High-impedance chopper-modulated input. Filtered output to drive balancing grid or follower. ($60.00)

SERRASSOID GENERATOR: Model K2-G produces a fixed triangular wave of 100 V peak-peak, at 500 kcps. Use it for a quadratic rounding in diode networks, and for many other non-linear recreations. ($29.00)

PHILBRICK *uses these octal-plug-in modules, and many others like them, in their standard computing instruments. They are tried and true, compact, convenient, and economical. You too can find profit and happiness with their help.*

All K2 Plug-ins run on plus and minus 300 VDC and 6.3 VAC. Socket wiring is simple and standardized. Write for freely given opinons on your applications.

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CIRCLE 38 ON INQUIRY

For Your 3-Ring Binder

NEW DATA SHEETS

For your free copy of the data sheets listed on this page, circle the appropriate number of the item on the Inquiry Card.

EXTREME TEMPERATURE TAPES including pressure sensitive and self-adhering Teflon, fiberglas and silicone rubber tapes for −100F to 500F electrical and mechanical applications; also included are silicone rubber and silicone rubber sheets, sponge sheets and silicone rubber-coated fabrics for −120F to 500F gasket, pad, cushion and diaphragm application. Conn. Hard Rubber Co., New Haven, Conn. Circle 217.

SELSYN TRANSMITTER-RECEIVER, designed expressly for industrial applications requiring sturdy equipment of moderate rotational accuracy, is subject of 2-page data sheet. Incorporated into its construction are such unusual techniques as completely encapsulated stator and rotor windings and a glass-like finish of both airgap surfaces allowing continuous immersion in water without loss of insulating quality or rust development. Rotron Controls Corp., Woodstock, N. Y. Circle 242.

SILICON TRANSISTOR CHOPPER (or modulator), a solidly encapsulated unit designed to alternately connect and disconnect a load from a signal source, may also be used as a demodulator to convert an a-c signal to d-c. An inertialess device that can be driven from d-c to hundreds of kilocycles, its dynamic range extends from a fraction of a millivolt to 10 volts and its operating temperature from −55 to +130C. Catalog includes 4 application diagrams. Solid State Electronics Co., Van Nuys, Cal. Circle 243.

SOLENOID VALVE bulletin covers a wide range of operating conditions for bronze valves at pressures to 400 psi and stainless steel types with four independent controls for variable opening and closing speeds, flow control and manual opening. J. D. Gould Co., Indianapalis, Ind. Circle 240.

INSUROK LAMINATED PLASTICS conforming to NEMA and military specifications are listed and described in catalog complemented by several tables of properties for the various grades of this versatile substance. The Richardson Co., Melrose Park, Ill. Circle 241.

"HANDBOOK OF CHEMISTRY AND PHYSICS", a complete reference for chemistry, physics and mathematics, containing five indexed sections, is continuously revised and annually published. More than 100 pages of new and revised scientific facts have been added. Over 200 prominent authorities in all fields of science have collaborated under guidance of C. D. Hodgman, Editor-in-Chief. The Chemical Rubber Co., Cleveland, Ohio. Circle 232.

MINIATURE TERMINAL BOARDS available with four or eight turret terminals molded directly into the body material are described on data sheet. 1/8 inch diameter mounting holes can be supplied on either size. The standard molding compound is mineral filled Melamine (MIL-M-14E, Type MME). Included are electrical and mechanical ratings, alternate molding compounds and outline and mounting dimensions. Electronic Sales Div. DeJur-Amsco Corp., Long Island City, 1, New York. Circle 249.

7/8 INCH CAPSULAR PRESSURE ELEMENTS for either internally or externally applied pressures, in ranges from 15-350 psi, have excellent linearity and very low hystersis and are desirable for miniaturization purposes. Bulletin gives further information, with material and performance specifications. The Bristol Co., Waterbury, Conn. Circle 234.

MINIATURE SILICON RECTIFIER, rated at 750 milliamperes d-c with voltage ratings of 200, 400 and 600 volts, are encapsulated into a volume less than .004 cubic inch. The new line has the lowest priced 750 milliampere silicon rectifiers on the market to allow wide commercial use. Sarkes Tarzian, Inc., Rectifier Div., Bloomington, Ind. Circle 239.

HIGH TEST SOLENOID AIR VALVES have fast-cycling, uninterrupted and dependable operation. Cycling tests for these new solenoids have passed the one hundred million mark without adverse effect. Featuring water-proof coils, the new units have been incorporated on all standard crescent four-way valves. Barksdale Valves, L. A., Cal. Circle 226.

HIGH-INTENSITY CARBON-ARC PRINTING LAMPS are made especially suitable to printed-circuit production processes by use of a point source of light and absence of under-cutting. Exposure time is sharply reduced. Principal light source is at the crater rather than in an uncertain flame. Accurately formed reflectors gather light from its source and distribute it so as to obtain utmost uniformity and maximum coverage. The Strong Electric Corp., Toledo, Ohio. Circle 227.

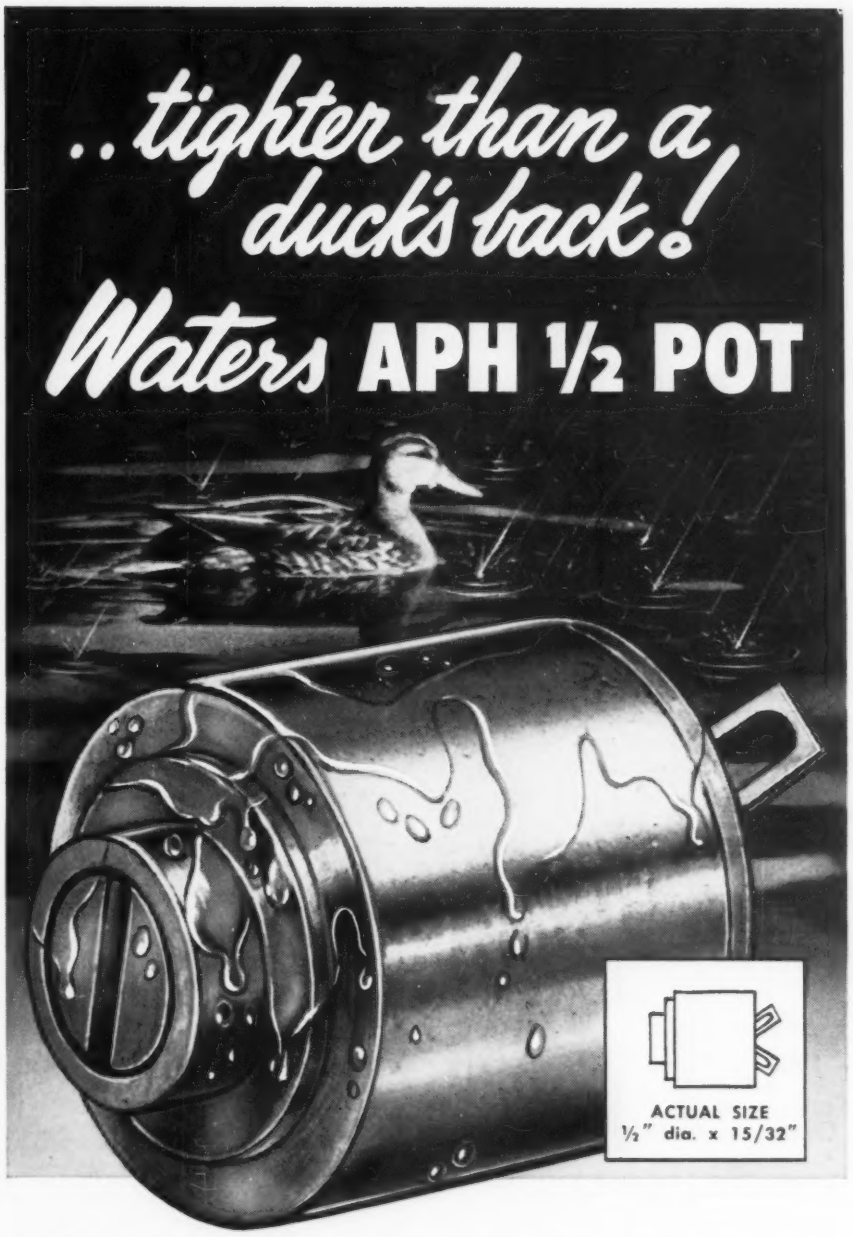
THREE SMALL RIGHT-ANGLE HIGH-VACUUM VALVES for pneumatic or manual operation offer lower impedance than vacuum globe valves of the same nominal size. Made of cast bronze and available in ½-, 1- and 1½-inch sizes, connections for the new valves may be made with a solder joint or standard NPT pipe thread connection. Consolidated Electrodynamics Corp., Rochester, N. Y. Circle 228.

SUBMINIATURE SERVOMECHANISM Model 20-200 is a versatile set of parts which can be assembled as a pre-engineered 1⅞-inch mechanism, fitting within a standard 2-inch diameter MS case and meeting Military Specifications. Supplied in kit or assembled form, the result can be any of a great variety of electromechanical components. Servo Development Corp., Westbury, N. Y. Circle 229.

MINIATURE RHEOSTAT, smaller than many 1 or 2-watt potentiometers, is an all-ceramic-and-metal unit that dissipates 12½ watts. Bulletin contains such standard modifications as tandem assemblies, shaft locking devices, tapered windings, etc. Ohmite Mfg. Co., Skokie, Ill. Circle 238.

COMPLETELY TRANSISTORIZED DC POWER SUPPLY provides 24–32 volts at 100 amperes and has a DC current overload capacity of 125 amperes for a duration of 15 minutes. As described in specification catalog, Perkin Model No. M-1136A, operates from a 3-phase, AC input of 208 volts ±10%, 57-63 cycles per second, with output impedance of less than 0.025 ohms from 0-2CKC. Perkin Engineering Corp., El Segundo, Cal. Circle 230.

HEAVY-DUTY FOOT SWITCH for use on machine tools, presses, motors, etc. are described on one-page data sheet. Switch has high electrical rating, oil-tight cast-iron enclosure and protective toe guard. Photograph, dimension drawing, characteristics, electrical rating and price information are included. Micro Switch, a Div. of Minneapolis-Honeywell Regulator Co., Freeport, Ill. Circle 244.



This new APH ½ Hermetical Seal Precision Potentiometer has been proven by Mass Spectrometer, "Radiflo" and other rigid leak detection tests.

Why pay extra for epoxy encapsulation, when Waters seals both ends of the APH ½ so tight that leakage is reduced as close to zero as you need. Its *"O" ring shaft seal* dams out moisture and salt spray. Its *glass-to-metal* seal minimizes leakage at the terminal lugs. Its *pre-tinned flange* eases air-tight soldering into the panel.

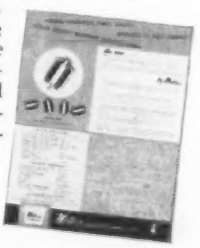
It's a "hot" pot, too! APH ½ derates to zero watts at 150°C. 1½ watts may be dissipated at 125°C. . . . 4 watts at 80°C.

Resistance range is from ½ to 100,000 ohms with a tolerance of ±5%.

Linearity tolerance is ±3% . . . tighter on request.

Meets military specifications: MIL-E-5272A, MIL-R-19, MIL-STD-202 and others as applicable.

Bulletin APH ½ gives you complete details about standard and optional electrical and mechanical specifications. Write:



Waters® MANUFACTURING, INC.

BOSTON POST ROAD, WAYLAND, MASSACHUSETTS

CIRCLE 39 ON INQUIRY CARD

SILICONE SOLAR CELLS are subject of four-page brochure, detailing electrical and physical characteristics, giving complete design parameters and application notes on nine types of cells. Illustrated are spectral response curves, current voltage characteristics at various light levels and variations of available power according to temperature. Semiconductor Div., Hoffman Electronics Corp., Evanston Ill. Circle 223.

FLOW-CONTROL SERVO VALVES for use in a wide range of aircraft, missile, nuclear and industrial applications are available at maximum rated flows to 10 gpm at 1000 psi valve drop with operating supply pressures from 500-4500 psi and temperature range from −65F to +275F. Units in this series operate on electrical input power of approximately 50 milliwatts and weigh about 13 ounces. Moog Valve Co., Inc., E. Aurora, N. Y. Circle 231.

SILICON "PHOTO-VOLTAIC" READOUT CELLS with a response time of 20 microseconds or less depending on load resistance, relatively high power output, long life and a wide operating temperature range (from −65C to +175C) are described in brochure giving complete design details, theory of operation, and application notes concerning the product. Semiconductor Div., Hoffman Electronics Corp., Evanston, Ill. Circle 235.

ELECTRONIC TUBES CATALOG gives specifications on complete line, contains detailed applications and performance data covering power triodes, rectifier and clipper diodes, gas noise source tubes, TR tubes, pressurized wave-guide windows and ionization gauge tubes. Central Electronic Manufacturers, Div., Nuclear Corp of America, Denville, N. J. Circle 248.

CHROMALOX ELECTRIC STRIP HEATERS have four general purposes: keeping viscous and heavy compounds moving smoothly; for ovens and special purpose air heating; for tanks, kettles, drums, etc.; and for new or converted platens and other production equipment. 4-page bulletin with thirty-two illustrations presents typical examples for each purpose. Edwin L. Wiegand Co., Pittsburgh, Pa. Circle 245.

HIGHLY FLEXIBLE MULTICONDUCTOR CABLE consisting of copper conductors embedded in strong insulating layer saves weight and space, resists chemicals and moistures and is easy to use. Bulletin lists characteristics, standard dimensions and properties; instructions on usage given. International Resistance Co., Phila., Pa. Circle 236.

ELECTRONIC GO-NO-GO GAUGE described in four page bulletin is designed for frequency stability and comparison checks, motor-speed control, pressure and flow control, material-flow control, and other limiting situations occurring between 1 and 40,000 times per second. Computer Measurements Corp., North Hollywood, Calif. Circle 210.

PRE-AMPLIFIER CATALOG describes physical and electrical characteristic curves of pre-amplifier that can be driven by a signal as small as 200 microwatts—such as might be gained from small tachometer signal changes, photoelectric signals or a signal from a thickness gage. Control, Division of Magnetics, Inc., Butler, Pa. Circle 221.

PRESSURE-VACUUM CONTROLS CATALOG in condensed form provides large number of specifications and describes a wide variety of controls featuring general purpose, sensitive, extremely sensitive, dual switch differential, absolute and explosion-proof units. United Electrical Controls Co., Watertown, Mass. Circle 102.

FLEXIBLE SILICONE RUBBER HEATERS for greater application flexibility in the design of electric heating units are flexible, waterproof, very thin, available in any plain shape and adaptable to almost any area where heat up to 400 degrees F is needed. Watlow Electric Manufacturing Co., St. Louis, Missouri. Circle 222.

PRECISION SWITCHES for major home appliances, vending machines, automatic devices, signal and alarm systems and automatic controls are described in bulletin complete with circuit arrangements, force and movement specifications and electrical ratings. Unimax Switch Division, W. L. Maxson Corp., Wallingford, Conn. Circle 225.

RECYCLING TIMERS provide two adjustable and continuous time cycles. Timing elements are synchronous motor driven, automatic reset timers. Four-page bulletin. Also available: 8-page bulletin on explosion-proof timing controls. Industrial Timer Corp., Newark, N. J. Circle 218.

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STATIONARY BATTERIES have new corrosion-resistant positive grids made of Silvium which increase float-charge service life and also fit the battery for cycling service applications. This patented alloy is 100 percent more corrosion-resistant than pure lead. Exide Industrial Div., The Electric Storage Battery Co., Phila., Pa. Circle 190.

STRAIN GAUGE TRANSDUCERS can measure gauge, absolute and differential pressure for aerodynamic loading and environmental pressure and can be used with galvanometer and tape recording systems, telemetry and analog-to-digital data handling systems. Gulton Instr. Div., Gulton Ind., Inc., Metuchen, N.J. Circle 205.

LAMINATES AND MOLDINGS OF V-204 pre-impregnated materials will display superior strength and modulus retention at operating temperatures as high as 600F for extended periods of time. Very high temperatures may be tolerated for relatively short periods of time. V-204 is a high-heat-resistant, high-strength, phenolic resin for the pre-impregnation of fiberglas, asbestos, or other suitable reinforcing materials. Eli Sandman Co., Worcester, Mass. Circle 197.

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LONG LIFE SOLENOIDS employing a machine-type bearing as a plunger guide have almost unlimited solenoid life. Wear is decreased by the precision fit of this guide and plunger. Catalog 57-S5 and Pub. 649 give complete information. Automatic Switch Co., Florham Park, N. J. Circle 237.

MECHANICAL STOPS for precise control of rotary motion in instruments and gear trains are low inertia mechanisms with low starting friction yet high static torque. Data sheet includes mechanical characteristics and application formulas. Kearfott Co., Inc., Little Falls, N. J. Circle 246.

MOUNTING HARDWARE for Bourns' TRIMPOT and TRIMIT potentiometers are illustrated in a new specification sheet. Hardware quickly and easily adapts all Bourns' lead-screw actuated potentiometers to virtually any mounting situation. End-mounting brackets, side-mounting brackets, clip brackets and panel-mounting accessories are covered. Bourns Laboratories, Inc., Riverside, Cal. Circle 247.

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The protecting nylon insulation extends beyond both ends of the UNI-RING, eliminating metal-to-metal contact and preventing harmful wire-chafing in tight locations. The UNI-RING is color-coded to indicate conductor sizes.

UNI-RING's one-piece design insures electrical integrity, prevents heating, and eliminates noises caused by isolated metal parts.

For samples and complete details, write: OMATON DIVISION

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CIRCLE 2 ON INQUIRY CARD

SILICONE SOLAR CELLS are subject of four-page brochure, detailing electrical and physical characteristics, giving complete design parameters and application notes on nine types of cells. Illustrated are spectral response curves, current voltage characteristics at various light levels and variations of available power according to temperature. Semiconductor Div., Hoffman Electronics Corp., Evanston Ill. Circle 223.

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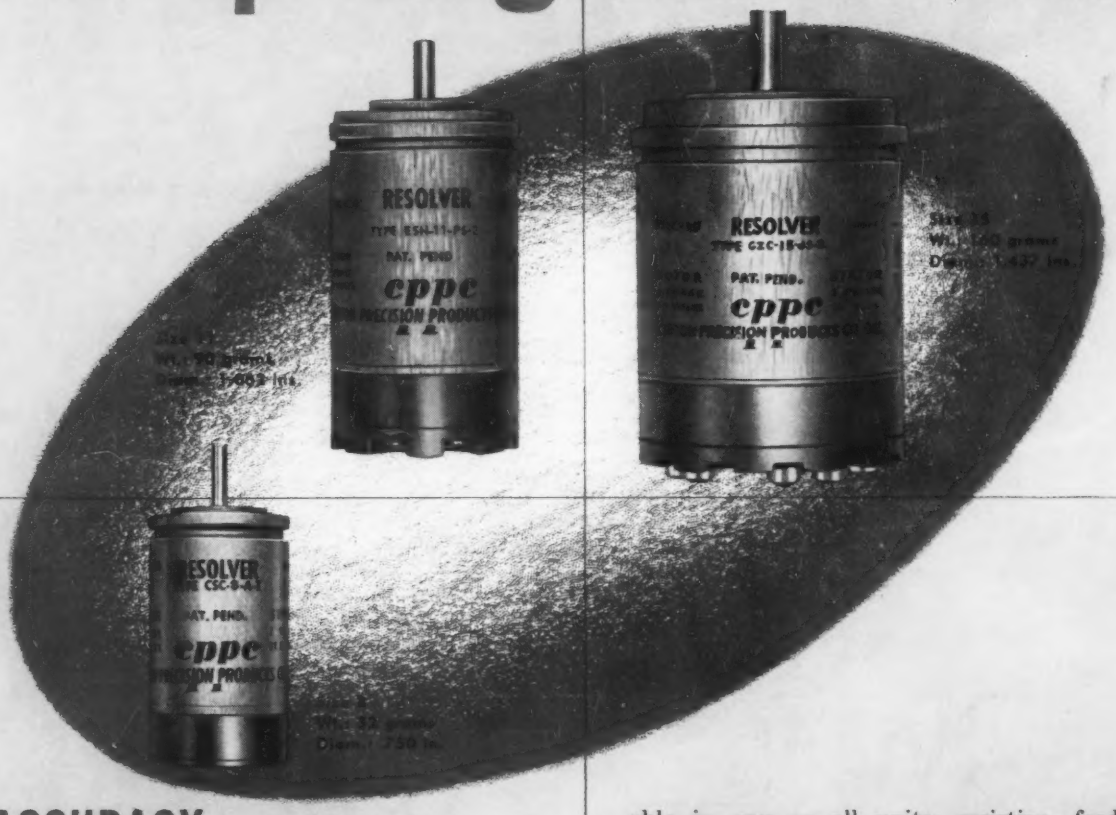
CIRCLE 2 ON INQUIRY CARD

Precision Computing Resolvers



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Highest accuracy in rotating components is a CPPC fundamental. Our Precision Computing Resolvers are no exception. Without compensation, a recent production run of resolvers showed functional errors of .06% *or less.* Perpendicularity of axes was ±3′ in 360°. Due to extreme symmetry of rotor and stator, nulls are excellent in these resolvers. Low phase shifts are also a feature.

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